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Institute of Correspondence Education

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B.A. Degree Course

SECOND YEAR

INDIAN MUSIC

Paper - III

Theory of Music - II

MUSICAL INSTRUMENTS AND ACOUSTICS

PACKAGE - 1

UNIVERSITY OF MADRAS

MADRAS - 600 005.

B.A.Degree Course
Indian Music

Paper - III
Theory of Music - II
Musical Instruments and Musical Acoustics
Package - 1

WELCOME

Dear Student,

We welcome you as astudent of the Second Year B.A.Degree Course in Indian Music.

This subject deals with Paper - III, Theory of Music - II, Musical Instruments and Musical Acoustics which you will have to study in the Second year of the Course.

The learning materials for this paper is being sent to you and will be supplemented by a few contact lectures.

You may be aware that learning through correspondence involves a great deal of self-study. We hope that you will put in your whole-hearted efforts.

On our part we assure you of our help in guiding you throughout the course.

Wish you all success.

DIRECTOR

II - SYLLABUS

PAPER III-THEORY OF MUSIC-II

MUSICAL INSTRUMENTS AND MUSICAL ACOUSTICS

I. Classification of musical instruments.

Study of the construction and tuning of -Tambura, Vina, Violin, Gotuvadyam, Flute, Nagasvaram, Mridangam.

II. Production and transmission of sound.

Musical sound and their characteristics-Pitch, Intensity and Timbre.

Laws of vibration of stretched strings. Vibration of air columns. Frequency and interval; Harmonics.

Free and forced vibration; Resonance, Sympathetic

vibration; Beats and Combination tones.

Absolute pitch and relative pitch; Just intonation and Equal temperament.

Acoustics of the auditorium - echoes and reverberation.

The role of Gramaphone and radio in the preservation and propagation of music. Recording, broadcasting and

telecasting.

III. Cycle of fifths and fourths. 22 srutis and their derivation. Consonance and dissonance.

IV. Lakshana of the following ragas:

(1) Bhairavi	(3) Madhyamavati
(2) Kambhoji	(4) Kedaragaula
(5) Dhanyasi	(6) Vasanta
(7) Sriraga	(8) Anandabhairavi

III - Scheme of Lessons

PAPER III-THEORY OF MUSIC-II

MUSICAL INSTRUMENTS AND MUSICAL ACOUSTICS

Lessons No.	Topics
1.	Classification of musical instruments.
2.	Study of the construction and tuning of Tambura, Vina, Violin, Gotuvadyam, Flute, Nagasvaram, Mridangam.
3.	Production and transmission of sound. Musical sound and their characteristics-Pitch, Intensity and Timbre.
4.	Laws of vibration of stretched strings. Vibration of air columns. Frequency and interval; Hormonics.
5.	Free and forced vibration; Resonance, Sympathetic vibration; Beats and Combination tones. Absolute pitch and relative pitch; Just intonation and Equal temperament.
6.	Acoustics of the auditorium-echoes and reverberation.
7.	The role of Gramaphone and radio in the preservation and propagation of music. Recording, broadcasting and telecasting.
8.	Cycle of fifths and fourths. 22 srutis and their derivation. Consonance and dissonance.
9.	Lakshana of the following ragas: (1) Bhairavi (3) Madhyamavati (2) Kambhoji (4) Kedaragaula
10.	(5) Dhanyasi (6) Vasanta (7) Sriraga (8) Anandabhairavi

IV–OVERVIEW

This package of learning materials deals with all the lessons as per the 'Scheme of lessons'.

V – STUDY UNIT
LESSON -1

CLASSIFICATION OF MUSICAL INSTRUMENTS

We have a rich variety of musical instruments varying in shape, size, consturction, tone colour, and technique of play, belonging to all the three main groups, stringed wind and percussion. The important features of these instruments is that in almost all the instrument there is provision for bringing out all the nuances of the melodic as well as rhythmic aspect of music.

The musical instruments used in India can be classified under many heads:

A

1. Stringed instruments
2. Wind instruments
3. Percussion instruments

In stringed instruments the sound is produced by the vibration of strings. Stringed instruments are called Chordophones in English, Tata vadyas in Samskrta and Narambu kaurvigal in Tamiz. Examples of stringed insturments are Tambura, Vina, Gotuvadyam and Violin.

In wind instruments the sound is produced by the vibration of air column in a tube. Wind instruments are called Aerophones in English, Susira vadyas in Samskrta and Tulaikkaruvigal in Tamiz. Examples of wind instruments are Flute, Nagaswaram, Shehnai and Ottu.

In percussion instruments the sound is produced by the vibration of a stretched skin or by the vibration caused by striking two solid pieces of wood or metal.

Those instruments in which sound is produced by the vibration of the skin are called Membranophones in English, Avanaddha vadyas in Samskrta and Tol karuvigal in Tamiz. Examples - Mrdangam, Kanjira, Suddha maddalam and tavil.

Those in which the sound is produced by the vibration of the metal or wood are called Autophones or Idiophones in English, Ghana vadyas is Samskrta and Kanjakkaruvigal in Tamiz. Examples - chipla cymbal jalra.

CLASSIFICATION OF STRINGED INSTRUMENTS

I.

The stringed instruments may be classified as follows:

a. Bowed :Also called Dhanvija in Samskrta. e.g. Violin Sarangi and Dilruba.

b. Plucked : It is also called Nakhaja. e.g., Vina, Gottuvadyam and sitar.

c. Strúck : Those struck with a hammer or a pair of sticks. e.g., Santur, Gettuvadyam, Piano.

Bowed instruments have 2 varieties

i. Those with plain finger board. e.g., Violin, Sarangi

ii. Those with frets: e.g., Dilruba, Esraja

Plucked instruments also have 2 varieites:

i. Those with plain finger board - e.g., Gotuvadyam, Sarod

ii Those with frets - e.g., Vina, Sitar

II.

Stringed instruments may also be classified as follows.

i instruments played on open strings -e.g., Tambura, Ektar, dotar

ii where in strings are stopped and played - e.g., vina, Gottuvadayam

CLASSIFICATION OF WIND ISNTRUMENTS

1.

a Wind instruments in which the wind is supplied by a mechanical contrivance, commonly bellows. e.g., Harmonium

b Those in which the wind is supplied by the breath of the performer. e.g., Flute, Conch, Nagasvaram, Ottu.

2.

a Those in which the wind is blown through an orifice in the wall of the instruments. e.g., Flute

b Those in which the wind is blown through vibrating reeds or tongues or mouth pieces. e.g., Nagasvaram, Ottu, Mukhavina

3.

a Those which have pipes with finger holes. e.g., Flute, Ngaswaram,Shehani

b Those which have pipes without finger holes. e.g., Gaurikalam, ekkaklam, kombu

4. According to the material with which they are made, the wind instruments may be classified into

a wood wind instruments. e.g., Flute, Nagaswaram and Clarinet

b brass wind instruments. e.g., Tirucinnam, Ekkalam

CLASSIFICATION OF PERCUSSION INSTRUMENTS

1.

a Skin covered instruments or avanaddha vadyas. e.g., Mrdangam, Tavil

b Instruments made of wood or metal called ghana vadyas.e.g., Cymbals, Jalra, Cipla

2.

a In some avandaddha vadyas the skin is stretched over an open circular frame of wood or metal. e.g., Kanjira, Tambattam, Suryapirai.

b In some the skin is stretched over a hollow body enclosing air inside. e.g., Damaram, Tabla.

3.

a In some avanddha vadyas the skin is stretched over one face of the instrument. They are called Ekamukha vadyas e.g., Kanjira, Damaram.

b In some of skin is stretched over two faces of the instrument. They are called dvimukha vadyas. e.g., Mrdgangam, Tavil.

c Pancamukha vadya with five faces, as seen in the Tyagarajasvami temple at Tiruvarur.

4. Based on the manner of play, the drums may be classified into:

a Those played by the two hands. e.g., Mrdangam

b Those wherein the hands are struk by a pair of sticks.e.g., Damaram, Nagara.

c Those in which are one face is played by the hand and the other face by a stick. e.g., Tavil

d Those which are self sturck. e.g., Budubudukai

e Those in which one side is struck with a stick and the other stroked by a flat piece of stick. e.g., Urumi.

5. According to the shape of the instrument percussion instruments may be classified into:
   a) Barrel shaped drums: Mrdangam, Dolak
   b) Cylindrical drums: Chenda, Pambai
   c) Hourglass shaped drums: Udukkai, Budubudukai, Timila.
   d) Pot shaped drums: Ghatam, Tantipanai
   e) Cup shaped drums: Nagara, Bheri.

6. Tunable instrument : Mrdangam

7. Tala vadyas also may be classified into :

a Pradhana tala vadya - those tala vadyas which are indispensable for a concert are called pradhana tala vadyas. e.g., Mrdangam, Tavil etc.

b Upa tala vadyas - those vadyas which may or may not be used in concerts are called upa tala vadyas.e.g., Ghatam, kanjira.

B

Musical instruments may also be classified under the follwing heads according to their utility in various types of concerts.

1 Music concerts:

a. Sruti vadya instruments which provide sruti accompaniment e.g., Thambura, Ottu, Sruti box.

b. Laya vadya - instruments which provide rhythmic accompaniment e.g., Mrdangam, Kanjira, Ghatam

c Sangita vadyas - those in which music can be played. e.g., Vina, Violin, Flute, Nagasvaram.

2. Those used in temples : Horns, Trumpets, Mukhavina, Conch, Panchamukhavadya.

3. Those used in martial music: Vira murasu, Bheri, Dundubhi.

4. Those used in folk music: Ektar, Tuntina, Magudi

5. Those used in class rooms for experimental purposes : Pradarsana vina, Grama-murchana pradarsini

C

Based on the number of notes they produce at a time instruments are classfieid into –

a. Monophonous instruments - instruments which give only one note at a time are called monophonous instruments. e.g., Flute, Ektar, Nagasvaram, Kanjira, Bheri. Human voice is said to be a monophonous instrument as it can sing only one note at time.

b. Polyphonous instruments - instruments which produce more than one note at a time are called polyphonous instrument. e.g., Violin, Vina, Gottuvadyam.

D

According to the status of the instruments in concerts they are classified as follows:

a. Pramukha vadya : Concert instruments like Vina, Flute and Gotuvadyam are primary instruments or mukhya vadyas.

b. Pakka vadya : instruments like Violin Sarangi are also instruments used for accompaniment, or pakka vadyas.

E

Based on whether the instrument is played solo or whether it is used as accompaniment instruments are classified as follows.

a. Suskam: The instrument when played as solo

b. Gitanugam: i.e., the instrument when used as accompaniment to vocal music. e.g., Violin, Tambura, Mrdangam

c. Nrittanugam: instrument when used as accompaniment for dance. e.g., Flute, Clarinet, Mrdangam.

d. Dvayanugam or ubhayanugam are instruments used as accompaniments for both vocal and dance. e.g., Violin, Flute, Mrdangam.

LESSON -2

STUDY OF THE CONSTRUCTION AND TUNING OF MUSICAL INSTRUMENTS

1. TAMBURA

This is a classical drone instrument of India. Its parts are

a. strings	b. bridge	c. kudam
d. neck	e. dandi	f. tuning pegs
g. jivali	h. tuning beads	

It would be better if all the parts are made of the same wood. Jack wood is used to make a tambura. The wood has to be prepared jsut as it is done for the Vina. Kudam is made and at the centre of the kudam, bridge is fixed and strings run over it.

Dandi and neck:

The dandi is separated from the neck by means of a projecting ledge of wood. This is hollow and is covered by a thin piece of wood. The dandi is broader near the belly and narrower towards the neck. On the top plank of the kudam is placed the bridge. Over this bridge pass the four strings, viz.

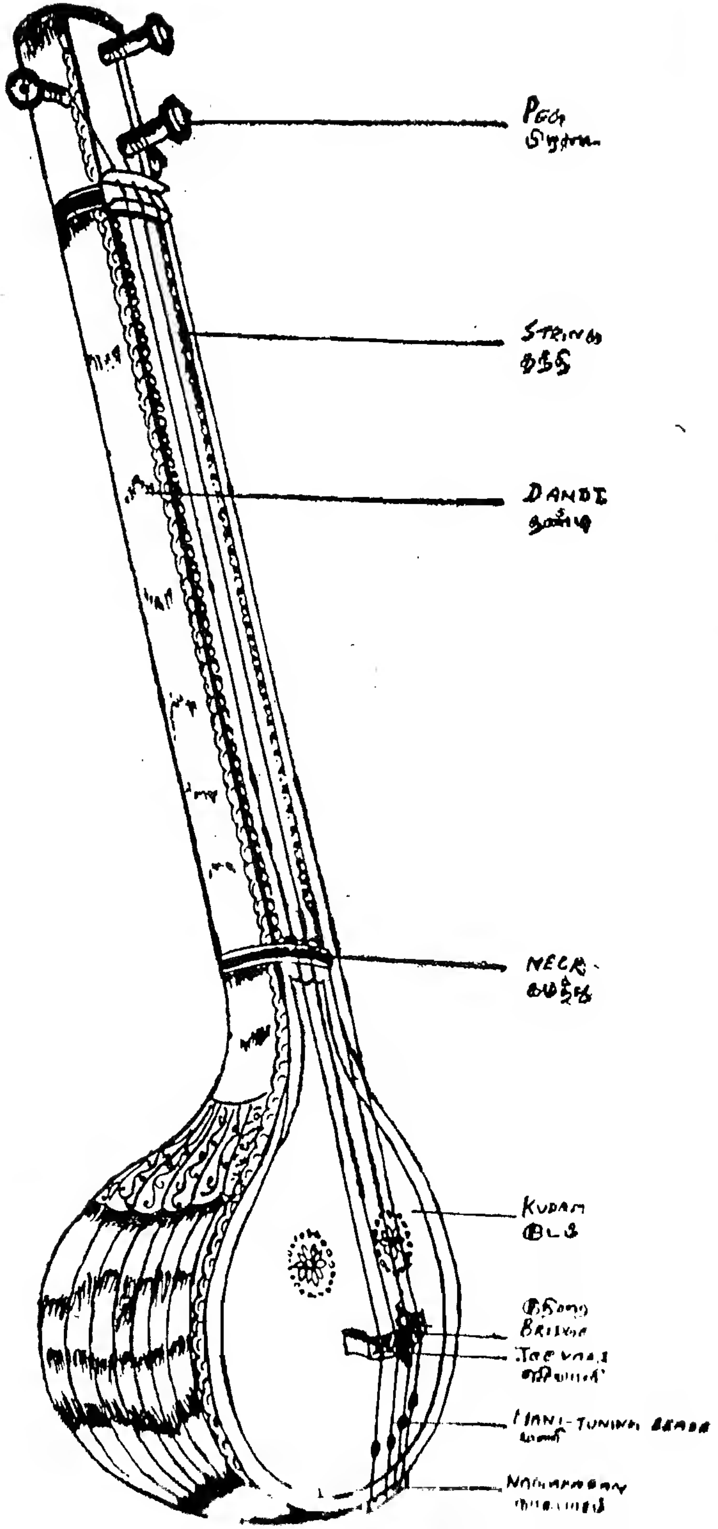
mandra pa - madhya sa - madhya sa - mandra sa .

Tuning Pegs :

Tuning pegs are fixed to the neck, two on top, perpendicular to the dandi and two one on either side of the dandi. They are made of wood. Into the holes of these pegs are inserted one end of the strings. The four strings pass through holes in a ledge fixed at the neck and over the dandi and bridge and are finally fixed to the attachment at the other end of the bowl. This metal attachment is the nagapasam beads of ivory or wood called pusula are threaded on the strings and they help to tune the instrument accurately. The strings are tuned to -

mandra pañcama, madhya sadja, madhya sadja, and mandra sadja respectively. They are also respectively referred to as pancama, sarani, anusarani and mandram strings.

TAMBURA



A bussing sound is produced when strands of silk thread are placed betwen the bridge and the strings. This is called jivali.

Tambura has holes near the bridge to emit the sound from the respondent body. Tambura is held upright with the bowl resting on the left thigh and the right hand twanging the strings. The strumming of the tambura helps to maintain a continuity of sound and is used to provide sruti to any music.

2. VINA

The principal parts of the vina are -

a. kudam	b. bridge	c. dandi
d. frets	e. tuning pegs	f. strings g. langar
h. yali		

Kudam:

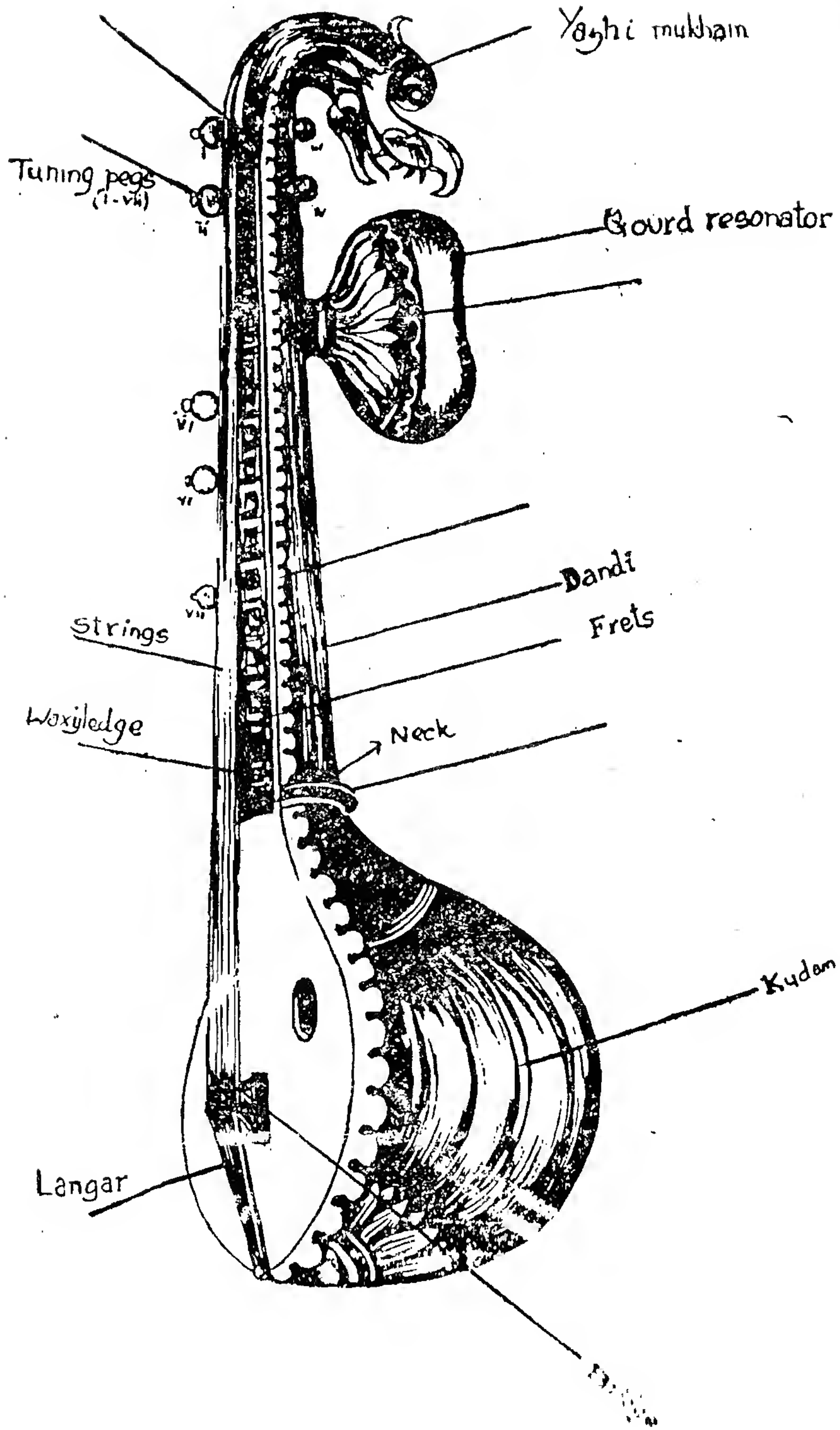
It is a pear shaped wooden instrument hollowed out of a big block of jackwood. This wood is got from trees which are about 50 years old. This wood is exposed to sun and rain and the seasoned wood is used to scoop out to get the required hollow shape pot like bowl. This pot or kudam can be of different sizes. This hollow pot is then covered on the top by thin flat covering, made of the same wood and fixed to the portion by pin like nails. The diameter of the covering plank varies according to the size of the kudam. Usually it will be about 10" to 12" in diameter though sometimes they are of 4" also for smaller kudams.

The depth of the kudam will be from 9" to 10" to be in proportionwith the kudam and its top. Deeper the kudam louder will be the sound.

Bridge:

The bridge also made of wood is placed almost at the centre of the covered top of the kudam. Its construction deserves special attention. The bridge made of wood is in the shape of an arch. On the top of this wooden bridge a rectangular piece of bronze plate is glued permanently. On top of the wooden bridge and adjacent to the longerside of the metallic plate, there is a strip of wood with four grooves for the four strings to pass through. A small arc shaped metal bridge is attached to

VINA



the main one. This is for the three side strings to pass through. The side strings are plucked to indicate the tala.

And close to the bridge, near the two feet, are a number of holes in circular formation. These are provided to gurantee good resonance to the vibrating sound of the instrument.

Dandi:

The dandi of the vina is made of the same wood as the bowl or kudam. A projection separates the stem of the dandi from the kudam.The stem is also hollow. The neck is attached to the dandi with ivory ornamental joints and usually curved downwards ending with what is called Yali mukham (resembling a dragon head). At the yali-end of the stem the instrument is supported by a gourd or soraikkai and forms a rest for the vina. It also helps in contributing to amplification and timbre.

Frets :

The frets are made of bell metal of best quality. Frets are small cylindrical rods about 1" to 2" long. They are fixed on the wax base which runs along the dandi. This wax base is made flexible through gentle heating so that the frets may be positioned for the required pitches. A total of 24 frets are fixed over the length of the dandi and the Vina has a general range of three and a half octaves.

Tuning pegs:

For the four main strings there are four pegs, placed two on either side of the neck. The pegs for the side strings are placed on the side of the stem near the player. The strings are tuned to -

anumandra-sthayi pancamam, mandra-sthayi sadja, mandra-sthayi pancamam and madhaya-sthayi sadja.

The three side strings, in the descending order of height, are respectively tuned to -

madhya-sthayi sadja, madhya-sthayi pancama and tara-sthayi sadja.

The anumandra pancamam and mandra pancamam are of copper wound steel strings while the rest are of plain steel.

Langars:

Seven in number, one for each of the seven strings, these can be called metal fastenings. At one end they are attached to the nagapasam which is fixed to the extreme end protruding over the top plank. A small projection from the nagapasam with a gap between it and the top plank, allows the langars to be fastened to the nagapasam. The other ends of the langar are attached to the seven strings, which pass through the grooves on the bridge and which in turn are fastened to the seven tuning pegs.

All types of gamakas can be played on this instrument.

Places like Tanjavur, Mysore and Vijayanagaram are famous for the manufacture of Vinas.

3. VIOLIN

The principal parts of the violin are -

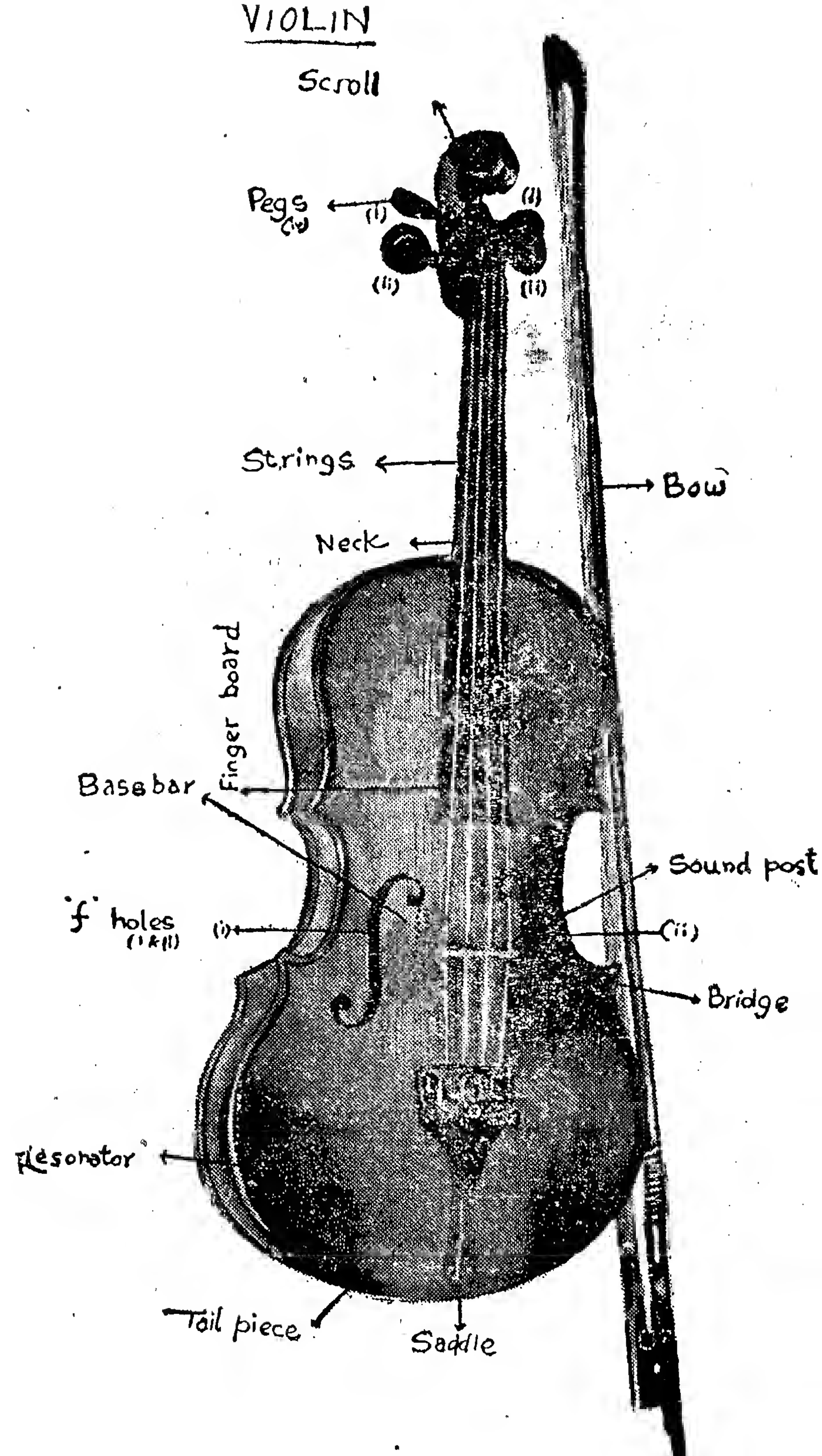
1. body or resonator with the'f'holes on it

2. bridge	3. the bassbar	4. sound post
5. neck	6. finger board	7. tail-piece
8. pegs	9. strings	10.bow.

Body:

The body of the Violin is made of the wood of pine and maple trees. Like choosing the wood for the Vina, we have to pay attention to the choice of the wood, which must be atleast 30 years old and well seasoned. The top plank or the belly, as it is called, of the Violin will be slightly elevated in the middle of the body and is made of pine wood, silver oak or sycamore.

The back plank of the violin is usually made of maple wood. When the instrument is made to vibrate the wood must be strong enough to withstand the penetrating sound produced. The belly and the back are separated by thin pieces of wood, called ribs.



The'f' holes are helpful in spreading the air enclosed in the body of the Violin in an uniform manner. The body has a curve on both sides

Bridge :

The bridge the bass bar and the sound post are vital parts of a Violin. The bridge is made of spruce wood or beech wood but is very strong. The height of the bridge should not be less than 2/3 of the height of the sound post. Its position is in the centre, on the top of the violin. Strings rest on them when they are kept in tension.

Bass Bar :

Just beneath the left foot of the bridge (as it faces the finger board), a thin piece or strip of wood is placed on the lower side of the belly. It is inside the body and cannot be seen. It supports the bridge from inside the body.

Sound Post :

The other important part is the sound post fixed at the right foot of the bridge, kept in a tight position between the front and back of the Violin.

The Neck and Finger-board :-

Neck is also made of maple wood, and is secured to the body without screws and nails. It appears as a continuation of the back.

Finger board is made of ebony. It is fixed on the top part of the neck and entends over the belly with a gap of about ". The curve of the finger board, slightly elevated in the centre resembles the curve of the bridge though a little flattened.

Tail-piece :

Tail piece is an almost triangular shaped piece of ebony, at the wide base of which there are four holes into which the strings are hooked. The other end of the tail piece is fastened by means of a gut or wire to a ebony button, which is a thick nail like wooden piece.

The button is fitted into a hole at the centre of the rib on top of the violin.

Pegs

The tunning pegs are four in number and are placed in the peg-box which is just continuation of the neck and the othr end of which ends in an ornamented portion referred to as the scroll. There are two pegs on wither side of the neck.

For fine adjustments in tuning, adjusting screws or adjusters are fixed to the tail piece and the strings are hooked to the adjusters.

Strings

The strings are made of gut and steel, the former for lower octave pitch and the latter for higher pitch. They are tuned to mandrasthayi sa, mandrasthayi pa, madhyasthayi sa and madhya- sthayi pa.

Instead of gut aluminium or some chromium electro-metal wound steel strings are also used.

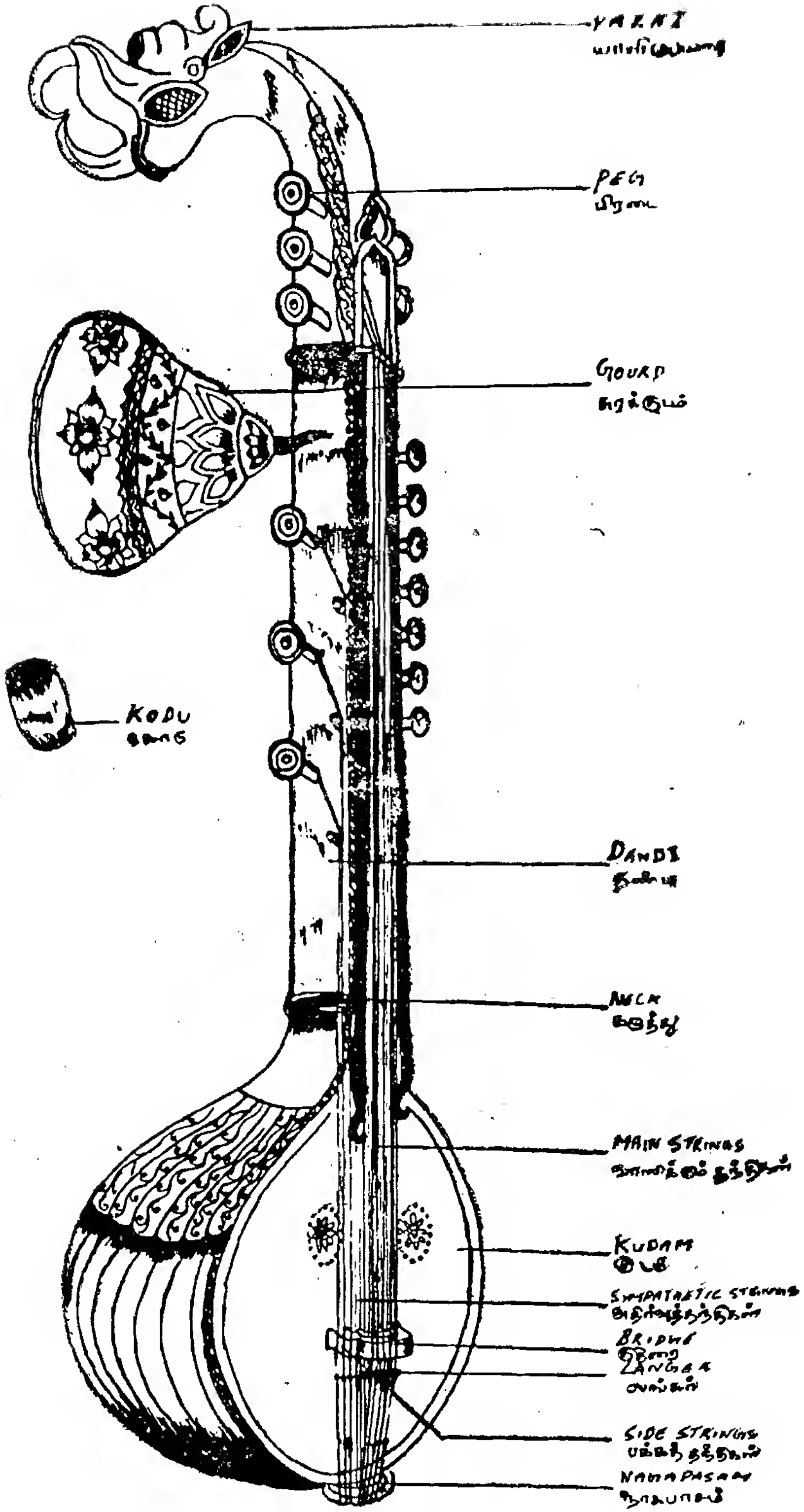
Bow

The bow is made up of three parts - the stick, the hair and the frog.

The bow-stick is made of brazilian wood. It has a slight bend or curve in the centre. About 175 to 260 white horse hairs are laid evenly side by side and are fixed into a square hole in one end of the bow and on the other to a separate wooden part called the frog. The frog is fitted into long slit in the bow. The frog is kept attached to the bow by means of a long screw which when tightened helps in adjusting the tension of the bow hair.

4. GOTUVADYAM

It is a stringed instrument similar to Vina but has no frets. A range of nearly four octaves can be played on this. The right hand fingers pluck the strings. A small cylindrical or barrel shaped wooden piece is held in the left hand and by gliding it over the strings and stopping at the required length on the stings, notes are produced. By varying the tension



GOTTU VADYAM

or length of the string, gamakas are produced, different from the method adopted in Vina where kampita gamakas are produced by deflecting the strings.

There are five main playing strings.

The first two strings, nearer to the performer, are tuned to madhyasthayi shadja,
the third string is tuned to mandra pachama, the fourth string to the mandra sadja and
the fifth string to anumandra pancama.

There are three side strings for sounding the sruti and indicating tala.

The instrument is provided with sympathetically vibrating strings which pass over a small bridge beneath the main bridge and over the finger board below the main strings. There are seven such sympathetically strings and they are fastened to the screws or pegs placed on the dandi facing the player.

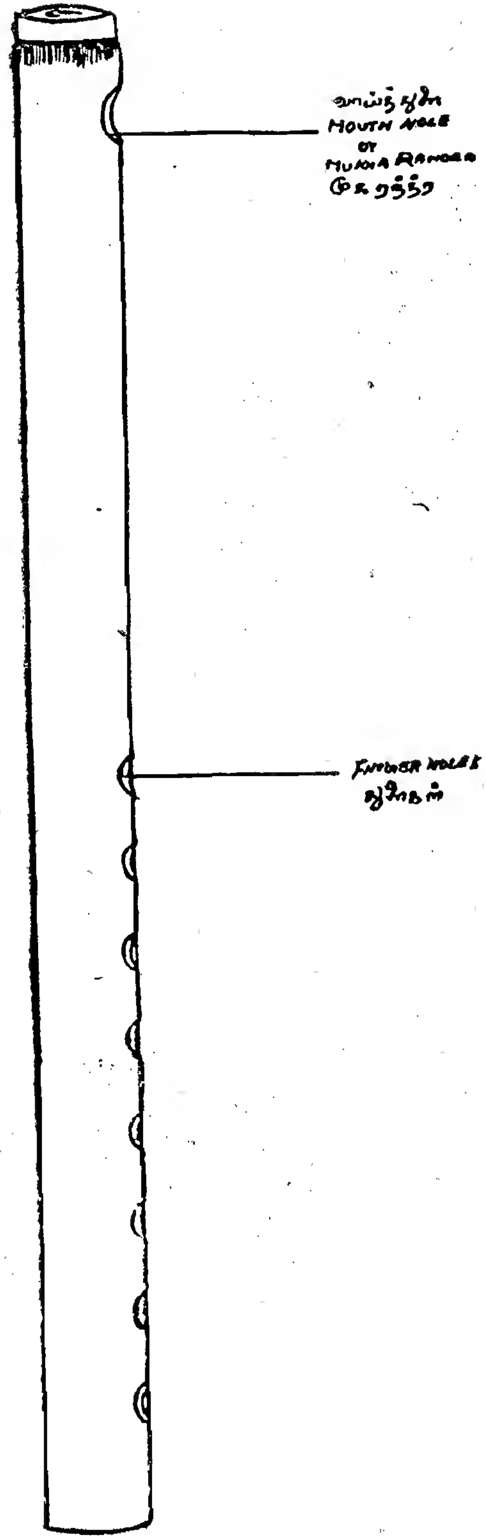
These strings are tuned to the notes of Harikambhoji raga or to the scale of the raga that is being played or merely to sa and pa. When the corresponding plain svaras are played on the main string these strings vibrate in sympathy and their vibration will increase the volume of sound and add to the toanal beauty.

This instrument has also been referred to as Mahanataka vina.

5. FLUTE

Flute is a simple cylindrical tube of unifrom bore closed at one end. Generally the length of the tube is 14" and its cross section about three fourths of an inch.

The mouth hole, or mukharandhra i.e., the hole used for blowing air is pierced 3/4 of an inch from the closed end. Eight finger holes or some times nine are pierced in uniform size and they are smaller in size than the mouth hole.



FLUTE

The finger hole nearest to the mukha randhra is the hole in which a svara of highest pitch in the instrument can be produced. Therefore it is called as tara randhra. All the holes are in straight line.

Flutes can be made of ivory. sandalwood, cane read, gold or silver. But bamboo flute is considered the best.

The flute is played by blowing air obliquely against the mouth hole. The variations in pitch are caused by changing the length of the air column by closing and opening of the finger holes. The flute is held in a horizontal position and played. While the two thumbs hold the flute in position the three fingers of the left hand, leaving out the little finger and four fingers of the right hand are used to close and open the finger holes.

Normally the flute is held to the right side of the performer and played. The different svaras separated by small and subtle intervals are played by partial closing and opening of the holes. Fast passages can be played accurately. Flutter tonguing is a special technique for playing fast passages when the centre of the tongue is made is to vibrate in a tremulous manner. The flute is a monophonous instrument and can cover 2 octaves.

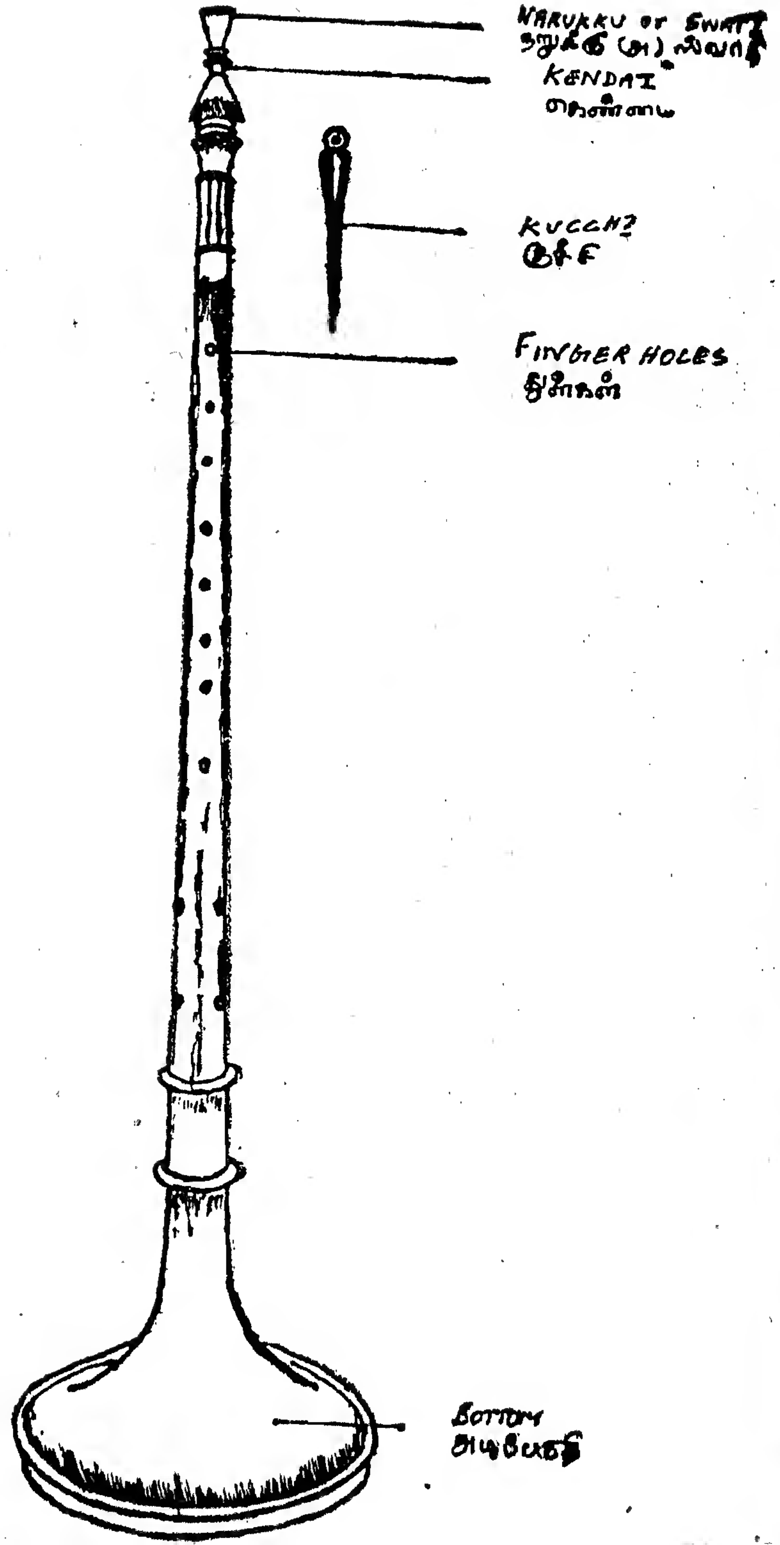
6. NAGASVARAM

Called also as 'Náyanam' it belongs to the family of wood wind instruments. It consists of wooden conical bore narrow at the top and enlarging downwards. The wood used for the body of the instrument is acámaram. It is also made of sandalwood, ivory or silver. Even stone nagasvarams are seen in some temples.

The nagaswaram has 7 finger holes. There are 5 other holes drilled at the bottom and these serve in controlling the accuracy of svaras produced through the playing holes. Of these 5 holes, 2 pairs are placed opposite to each other near the lower end. They are called brahma svaram. The fifth hole, i.e., the lower most is called adhara svaram.

The wood used should be at least sixty years old. There is a metal staple at the top and it is called 'melanaisu'. A small metallic cylinder called 'kendai' is introduced and into this is inserted a mouth piece called 'narakku' which is also called 'Sivali'. This is made out of a reed called

NAGASVARAM



'korukkai'. These reeds are also seasoned. A metallic bell is seen at the bottom. Sometimes, the staple, at the top, the bell at the bottom and the bore of the body of the instrument are of the same wood.

Two varieites of nagasvaram are seen. The 'timiri' variety is shorter in length and higher in pitch. The 'bari nayanam' is long and has a vibrant tone.

Besides the spare reeds to be used while playing a bodkin of ivory or horn is used to clean the metal stape at the top and the bell at the bottom.

The system of fingering while playing is similar to the flutes but the subtle differences in pitch are produced by skilful adjustment of the air that is blown. Exercises in tuttukaram i.e., puffs of air characteristic of particular gamakas and passages are practised.

The nagasvaram is always accompanied by the tavil for rhythmic accompaniment which is played even when raga alapana is played.

Ottu is the other wind instrument which provides a constant drone accompaniment to the nagasvaram.

Nagasvaram is played in temples during rituals and in social functions like marriages and is regarded as a 'mangala vadyam' (auspicious instrument).

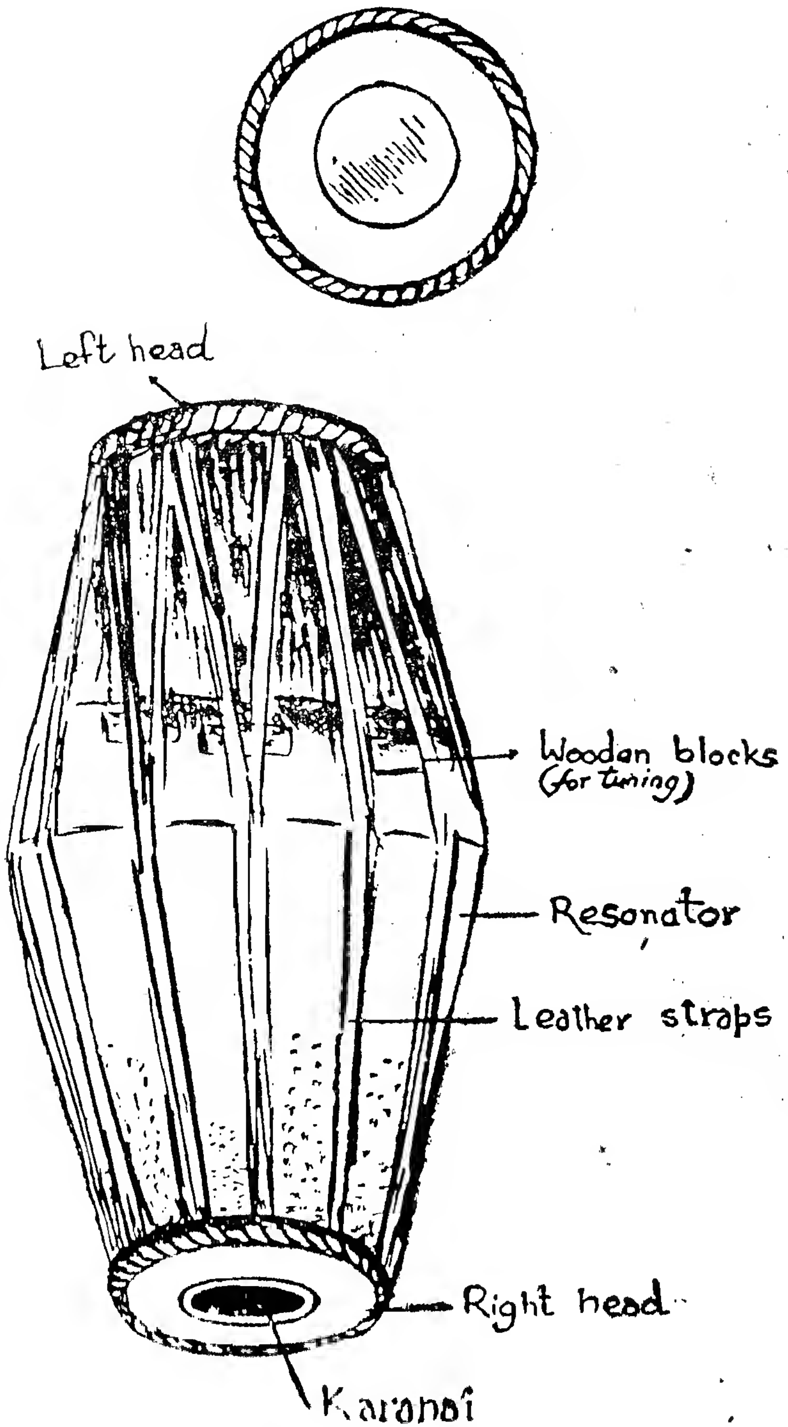
7. MRDANGAM

The body of the mrdangam is scooped out of a single bock of wood. Jack wood, redwood, margosa or the core of the coconut tree are used. The shape of the body of the mrdangam can be compared to two bottom less flower pots joined at their rims.

The dimensions of the mrdangam for taggu sruti (low pitch) are –

the length 24"
the diameter at the centre 11"
the diameter at the left side 7"
the diameter of the right head is 6"

MRDANGAM



the length of the left half of the instrument 10"
the length of the right half is 13"
the thickness of the shell -
9/16" on the right side
10/16" on the left side
3/4 in the middle.
For heccu sruti (high pitch) –
the length is 22"
the diameter at the centre is 10"
the diameter of the right head is 6"
the diameter of the left head 7"
the length of the left half 9&3/4"
the length of the right half 12" the thickness of the shell -
right side - "
left side - 9/16"

The right playing face of the instrument is tuned to the basic pitch or the adhara-sadja of the main performer. This face has three layers of skin. The innermost is hidden from the view. The layers are called -

vettu tattu,
kottu tattu
and utkarai tattu.

The outer ring is called 'mítu tól' and the inner ring 'cápu tól'. Calf skin is used for outer ring and sheep skin for inner ring.

In the centre of the right face is a circular black paste, which is composed of manganese dust, boiled rice and tamarind juice. Sometimes boiled rice and iron filings are mixed and applied. The stone called kittán is powdered, mixed with rice and used. The black paste called cittam is applied on the inner skin in small grains in finely rubbed, with polished surface of a hard stronc. The paste is thickest in the centre and thins out at the edges.

The left face consists of two rings. The outer one is buffalo skin and the inner one is of sheep skin.

At the beginning of the concert paste made out of ravai (súji) is applied to this face to help maintain octave relationship with the right face which is tuned to adhara sadja.

On the two hoops of the mridangam there are sixteen inter spaces for the straps of buffalo skin to pass through. The pitch of the instrument is regulated by upward and downward strokes. on the hoops at suitable points by means of a stone or a small hammer.

LESSON -3

INTRODUCTION

Acoustics is that branch of physics which deals with the study of sounds, its cause and nature. While music is concerned with form and beauty that sound generates, acoustics is concerned with the problems of sound production, transmission, and perception of sounds in general.

Sound is produced by motion of some kind. In many cases the motion can be perceived by the eye. For example, when the string of a Tambura or Vina is plucked, it gives out a sound and at the same time the string swings from side to side. The moment the string is touched by the finger, the motion ceases and with it the sound. Thus sound is caused by the vibrating motion of some sounding body. In wind instruments sound is produced by the movement of the air inside a tube, and in the percussion instruments by the vibration of skin.

It is an established fact that all sounds are not of the same nature. The first difference that we notice is between that of a pleasant sound and unpleasant sound or between a musical sound and noise. In the case of noise we hear rapid and irregular changes in the sound. When a balloon is burst or anybody screams or cries, the resultant sound is noise.

How does a noise differ from a musical sound ? We can recognise that a musical note has a definite pitch and is therefore due to vibrations which follow each other at regular intervals. Noise is not a uniform sound. A musical tone strikes the ear as a perfect undisturbed and uniform sound while in noise various tones are irregularly mixed. Musical notes produce periodic vibrations, while the vibrations of noise are not so. Inspite of this irregularly even in a noise we can detect something resembling pitch, showing that in the midst of irregular vibrations there may be a few regular ones. It is however difficult sometimes to draw a sharp distinction between a Musical sound and noise. The sound of the ghatam and the kanjira, for instance, cannot strictly be called musical, but they are sometimes delightful accompaniments in a music concert.

1. PRODUCTION AND TRANSMISSION OF SOUND

Sound is produced by vibration. In many cases the movement may be perceived by the eye. For example, we pluck the string of a Tambura or

Vina, a sound is given out and at the same time the string swings to and fro. The moment the string is touched with the fingers the movement stops and with it the sound. Hence it is evident that the sound is produced by the vibrating movement of some sounding body. To analyse the method of process, a sounding body for example, the string of the tambura, when sounded gives a series of backward and forward movements to the layer of air next to it. This layer of air is set in motion by the impulse of the force of the sound. This in turn strikes the third layer and so on, till the compression reaches the Tympanum or the ear drum. The layer of the compressed air just in front of the ear gives a blow to it and pushes it backwards. This movement of the ear drum is transmitted to the brain as sound.

We also see that the layers of air do not go forward, nor are they displaced, it is really fine state of compression and rarification of the air. So it only moves backwards and forwards but does not move away from its original position. This compression and rarification is known as sound wave. The following experiment will prove that it is the condition of the medium and not the particles of air itself that is carried to the ear.

Experiment:

Since air and water have the same qualities in the transmission of sound, the water is taken to prove the transmission of waves. The circular waves set up when a stone is dropped into still water is a phenomenon familiar to all. Stones dropped into still water will form water weaves which travel along outwards in larger circles. If small pieces of paper are floated on the water they will move up and down and not away from where they were dropped. The waves will be stronger at the place where the stone is dropped and the waves move forwards till the extremities get weaker at the end. The same thing happens when air moves up and down. It is the disturbance that travels and not the air particle itself.

Transverse and Longitudinal wave propagation

There are two types of waves:

i. Transverse waves.

ii. Longitudinal waves.

Transverse wave is one in which sound is propagated in a direction perpendicular to the direction of vibration of the particle. Sound waves in stretched strings are tranverse waves.

Longitudinal wave is one in which sound is propagated in a direction same as that of the vibration of the particle.

In transverse wave propagation the direction of sound wave and direction of vibration of the particles are mutually perpendicular.

In longitudinal wave propagation the direction of sound wave is the same as or parallel to the direction of vibration of the particle.

Let us now see how these transverse waves and longitudinal waves are set up in the medium.

A tuning fork is used in the laboratory to emit notesof standard frequencies. It has two identical prongs forming a U connected to a stem called the shank. When the prongs are struck on a rubber pad they vibrate and emit notes of standard frequencies.

The intermediate particles arrange themselves in a wave curve. As the prong vibrates, to an fro, the vibrations of the particles are repeated. You might have noted that the particles vibrate in a direction perpendicular to the line of propagation of the wave. In other words transverse waves are set up.

Note: As mentioned earlier, here only the energy is transmitted the particles do not move away with the wave but only ocillate about their respective mean positions or rest.

Longituidinal waves

When the prong vibrates to and fro, they push out the air particles in front and then pull them in forming condensations and rarefactions in the surroundings medium. As the prong continues to vibrate, alternate condensations and rarefactions are transmitted in the medium. The progression of these compressions and rarefactions is known as a longitudinal wave. Here also the particle does not move away with the disturbance and only energy is transmitted.

In the case of a transverse wave, the upper extreme position is called a crest and the lower extreme position is called a trough the crests of a

transverse wave correspond to condensations of a longitudinal wave and the trough to rarefactions.

Medium

Sound requires a medium for transmission. Sound cannot be propagated through vacuum. This can be proved by the bell jar experiment. An electric bell is placed with in a bell jar and the jar is connected an exhaust pump. When the bell is connected to an electric battery it starts ringing. Now start exhausting the air from the bell jar by working the pump. The volume of the sound becomes lesser and lesser till one completely stops hearing it when all the air has been pumped out.

Now if the air is again let in, the sound begins to be heard again, softly first, and then gradually louder and louder. This shows that a vacuum cannot propagate sound. There should be some medium to carry the sound to the ear. Many kinds of sounds may also be propagated at the same time as is seen in a music hall or class room.

Air is not the only medium through which the sound is transmitted. Solid, liquid, and gas also transmit sound.

Placing the head against the table or bench, close one ear. Then sound a tuning fork and place the handle of the tuning fork on the table or bench. The ear is able to hear the sound very clearly. Again if one end of a wooden bar is held to the ear and other end tapped, the sound is perceived clearly by the ear, thus showing that solids transmit sound.

Vibrations are also carried through liquids. Suspend a tuning fork inside a cylinder with water. Set the fork to vibrate. Observe the note produced by the tuning fork. Then place a resonant box underneath the cylinder. Again repeat the same experiment. The sound will be reinforced by placing the cylinder of water with fork, on the resonant box. The vibrations transmitted through water is increased by the vibrations of the resonant box.

Audible Range

Do all vibrations produce audible sound ? You might wonder why the waving of hands or the movement of a pendulum is not heard. That is because these vibrations are very slow. Vibrations will not be heard if they happen to be too rapid or too slow. The average ear is sensitive to

16 to 40,000 vibrations per second. If the frequency of a body is below 16 hertz (vibrations per second) the sound is not audible to the normal human ear. Sounds with frequencies lower than 16 hertz are called infrasonics. similarly if the frequency of a body is above 40,000 hertz the sound is not audible to the normal human ear. Sounds with frequencies higher than 40,000 hertz are called ultrasonics.

2. MUSICAL SOUND AND ITS CHARACTERISTICS

Wave Motion

Wave Motion can be defined as the repeated motion of a series of particles, the motion being handed on from each particle to its neighbour. These compressions and rarifications which travel on to the ear drum are known as sound waves. A series of sound waves following each other in a medium along any line of propagation is known as Wave Train. The experiment illustrates the fact that it is a continuation of the medium and not the particles of the medium that is transmitted.

Wave Length

When sound is produced a series of compressions and rarifications are transmitted through the air and reaches the ear drum. One crest and trough in the water wave together make up a complete wave. The crest is the place where the portion of the water has been thrust up from the original surface. The trough is the place where part of the water has been sunk blow the original. A cork floating near the place of disturbance will be found to remain in the same place riding over a crest and rinking under a trough as the waves move forwards. The distance between the two neighbouring crests or troughs is called the **wave length.**

In the air also one compression and rarification make a complete wave and the distance between two successive compressions or raraifications make up the wave length.

Wave Amplitude

The wave amplitude is the extreme distance or the extent of the vibration of the particle from the resting point.

Wave Velocity

The rate at which these vibrations advance is called **Wave Velocity**. The magnitude of the velocity depends upon the condition and density of the

medium. If there are stronger forces or disturbances in the medium, the velocity is feeble and there is no free course for the waves. When the medium is light the magnitude of velocity increases and when it is dense the velocity decreases. Thus the velocity of sound differs with different media.

As the density of air is 1.29 grams per c.c. the velocity is 331 metres per second. But as the density of water is less i.e., 1 gram per c.c. the velocity is 1410 meters per second. Sound waves are subject to refraction and relfection as in the case of light.

Velocity of sound in a medium:

Distance travelled by sound wave in one second is called the velocity of sound wave.

Velocity of sound V = freqeuncy X wavelength

Reflection of Waves

Echoes are made by reflection. An echo will be heard only if the reflecting surface is far away from the source. If the reflecting surfaces is curved it may cause the sound waves to converge into a focus.

Refraction of Waves

Refraction occurs when the sound waves pass from one medium to another because the wave velocity changes due to differring density and other conditions.

The change in the temperature also accounts for refraction. The change in the temperature increases or decreases the density of the medium. When temperature increases it lightens the medium and velocity increases and when the temperature decreases it makes the medium heavier and the velocity will be less. Waves travel faster in warmer air than in cooler air. The refraction caused by temperature variation is a very common occurrence.

Wind also produces refraction of sound waves as it is an established fact that sound waves travel better with the wind than against it. The velocity of the sound differs when we go up from the ground. In the higher attitudes there is only less scope for disturbances and also the pressure of the air changes when we go higher and higher. This causes the sound

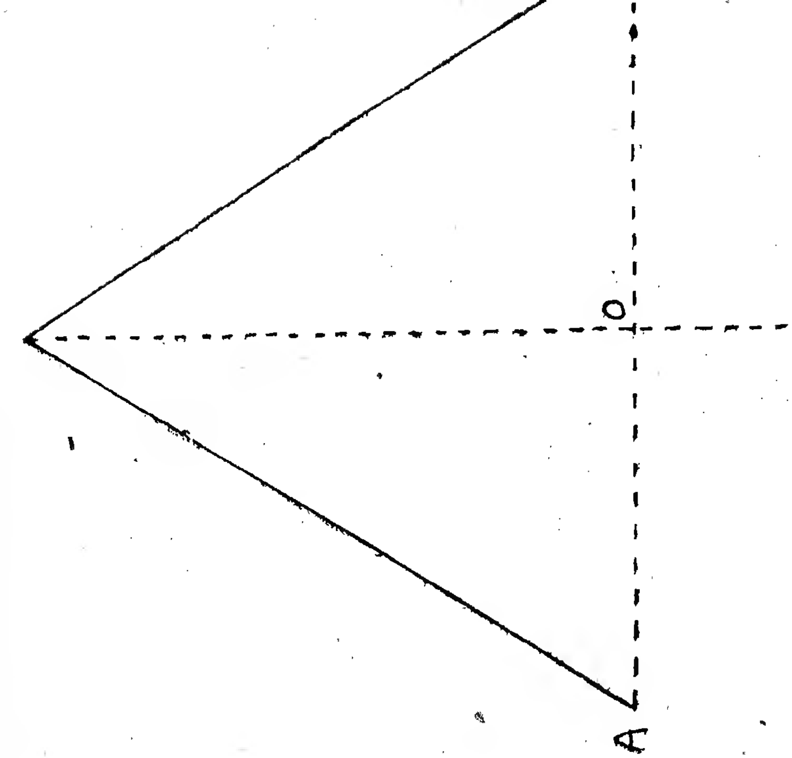


Fig. 2

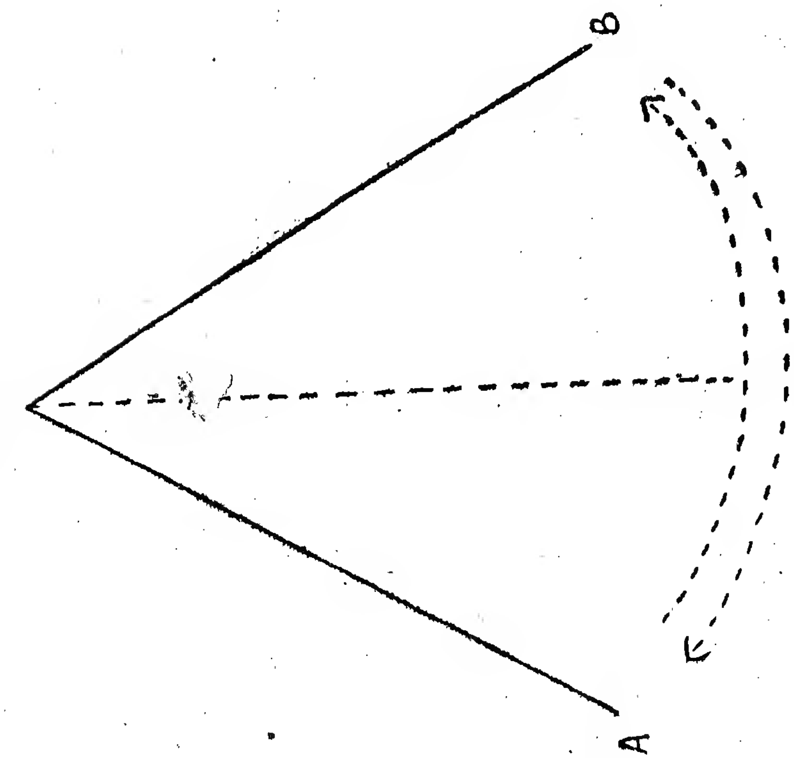


Fig. 1

to refract. The magnitude of the velocity hence depends upon the elasticity and density of the medium.

When sound passes through different media its frequency will remain constant, but wave length will change. hence velocity of sound is different in differet media.

We shall now familiarise ourselves with the 'terms' which often come across in our further discussion.

Virbation: Vibration is one complete to and fro motion.

In the fig.1 when the particle moves from A to B and returns to A we say the particle executes one complete vibration. The time taken to complete one vibration is called the time period of the vibrating body.

Frequency:

This is defined as the number of vibrations made per second by the vibrating body. When the frequency of a body is, say 256 hertz., this means that the body will execute 256 vibrations per second the unit of frequency is 'hertz' (1 hertz = 1 cycle or vibration per second).

Amplitude:

Amplitude of the vibration is the maximum swing OA or OB of the particle to either side of the equilibrium or rest position of the particle as can be seen in the fig.2.

Note:

1. The amplitude of the vibrating body gradually diminishes due to air resistance if its vibrations are not maintained by external arrangements.

2. The amplitude of vibration of a body remain constant if it is situated inside a perfectly evacuated container.

A. PITCH

Musical sounds arrange themselves in natural order according to pitch. It is the tonal variations that move up a melody when they are related to each other in a certain definite manner. Pitch is the height or depth of a note or that which distinguishes a note of lower sruti from a note of

higher sruti. Pitch depends upon, frequency, which is the number of vibrations the sounding body makes per second. When the number of vibrations per second increases the pitch becomes higher and as the number of vibrations per second decreases and pitch becomes lower.

If the frequencies of two notes bear the ratio 2:1, in former note will be found to be the octave note of the latter. This relationship is called Dvigunatva. The octave notes bear the dvigunatva relationship. In other words if the pitch of a note say like in Madhya sthayi antara ga is equal to 300 vibrations per second, the pitch of the tara sthayi antara ga is 600 vibrations per second and so on.

Pitch is expressed relatively when we say that one note is the Pancama or Madhyama of another note. It is expressed absolutely when its vibration number or frequency is mentioned. The pitch of a note can be expressed at the number of vibrations per second or it may be mentioned comparatively while comparing the pitch of a given note with another of the other.

B. INTENSITY

Suppose the string of the Tambura-is first plucked lightly and then with greater force, by drawing the string a little further from its position of rest, we are able to perceive a difference between the two notes though they are of the same pitch. We perceive that the intensity or loudness of the second is greater than that of the first. We easily recognise that the loudness of a musical note increases or diminishes with the amplitude or vibration of the sounding body. When the amplitude is larger the sound is louder and vice versa.

It is proved that intensity varies as the square of the amplitude. i.e., when the amplitude varies 3 times the intensity of sound varies by 9 times. In our houses if we want to have more loudness of the sound form the Radio we work on the volume control we manipulate to increase the amplitude to get louder sound.

The intensity is measured in terms of a unit called 'decibel'. A decibel is the smallest difference in the intensities of two sounds that the normal ear can distinguish.

We thus see that the intensity of the notes depends upon the amount of displacement of the string from the point of rest. It also depends upon

the density eondition in the temperature and the distanee of the listener from the sounding body.

Intensity of sound is greater in a denser medium.

a. An eleetrie bell sounds louder in a earbon di-oxide medium than in air medium as earbon di-oxide is denser than air.

b. Bell sounds louder in moist air medium than in dry air medium. This is the reason why a distant sound is better heard when the atmosphere is eold.

The direetions of the eurrents of air and also the presenee of other sounding bodies in the neighbourhood affeet the intensity. In theatres with poor aeoustics, inverted sound pots suspended over the stage serve as good amplifiers. For effeetive response, pots of various sizes should be used.

TIMBRE OR QUALITY

Musieal notes may also differ from eaeh other by their quality. The quality or eharaeter of musieal sound by whieh one is able to reeognise the voice of different persons and the notes of different Musical instruments is known as timbre. Eventhough the sounds are of the same piteh and loudness, yet one ean easily say whieh one has been produced by a Vina, whieh one by a Flute, Violin ete. A musieal instrument performs two funetions. Some parts are designed for the production of musieal vibrations and others reeeive these vibrations and amplify it. The quality of the instrument depends upon how these parts work together in eo- operation. So it depends on the manner in which the sound is exeited and also on the material and make of the instruments. In the case of the human voice quality depends on the size and strength of the larynx and the length of the voeal ehords.

When a sound is produeed there is present in it a fundamental tone or simply the fundamental and other higher tones called the Overtones or Upper partials (to be studied in the next lesson). The fundamental and the overtones origninate from the same source and blend into single musiele note. If the frequencies of the overtones are integral multiples of the fundamental they are called harmonics. The number nature and the relative intensities of the overtones and harmonics determine the timbre or the quality of a note.

LESSON NO. 4

1. LAWS OF VIBRATIONS OF STRETCHED STRINGS

When a string is not produeing sound it is said to be in a position of rest. If now it is pulled slightly to one side and released it moves backward and forward in an uniform manner, till the sound dies out. The backward and forward movement is known of vibration. That is if A is the position of rest and if the string moves to B on one side and back again to A, then the string is said to have made a eomplete vibration. Half of this movement is an oseillation.

The distanee the string has travelled on both sides of the position of rest in known as the amplitude of the vibrations. Amplitude is the extent of vibrations. -when a string is set in motionthe middle part whieh is seen to move baekwards and forwards is known as the antinode. There are two points of rest where the strings are fixed and these two points are known as the nodes. There is no motion on these two points which are the points of rest or the nodes.

Mersenne (1588-1648) of Paris with the help of the monoehord or Sonometer in order to study the variations in frequeneies of the stretched strings. It eonsists of a hollow wooden box on whieh a wire is fastened to a peg and passing over a pulley, the wire is kept tight by a weight. There are 2 movable bridges on the sound box on either side to adjust the variations in vibrating length. The purpose of the sound box is to give tonal effect to the sound emitted by the strings. He found out by experiments that the pitch of the strings depends upon 3 important eonditions.

1. The frequeney of the notes emitted by a string kept under constant tensión varies inversely as the length i.e., the greater the length, the lower the pitch.

Experiment : Ke[illegible] the two bridges 90 ems apart and pluck the wire and see the notes produeed. Arrange the bridges in sueh a way as the string will vibrate in its half of its length producing a nate an octave higher than the first. By sueeessively stopping, the string at a third and a quarter of its length. The notes Tara Sthayi Pa and Ati Tara Sthayi sa are heared by the respeetive lengths. Though these will be higher in pitch, they will not be higher octaves. We find that they are musically as well as mathematically related the frequency of the notes emitted by a string

kept under a constant tension varies inversely as its length. The greater the length of the string the lower the pitch or the shorter the length the higher the pitch.

Students of music can easily see this in the musical instruments like Vina and Violin. When the finger is kept on the first fret and the subsequent frets, the length of the string gets gradually reduced and the pitch gradually increases.

Likewise longer Flutes and Nagasvaram produce lower notes while shorter ones give out higher tones. In percussion instruments the smaller drum faces give higher tone and bigger ones give lower tones.

2. The frequency of a note emitted by a string whose length is kept constant varies directly with the tension i.e., the greater the tension the higher the pitch.

Experiment : Fix a strong string on the Sonometer and keep the bridges in a fixed position. After tuning it in unison with a tuning fork, now double the weight in the pan at the end of the string, thus doubling the force of tension. The pitch of the note now rises but not to the level of the next octave note. Add more weight till the next sthayi svara is obtained. The weight is now found to be 4 times that of the original. With 9 times the original weight Tara sthayi Pa is heard and 16 times the original will give a note 2 octaves above the fundamental. So while the frequencies are in the Ratio 1:2:3:4, the tensions are in the ratio 1:4:9:16, the greater the tension the higher the pitch.

In the stringed musical instruments the tension of the strings(in stringed into) is increased by means of the pegs. When the peg is turned in one direction the string gets tightened and loosened when turned in the other direction and consequently the pitch increases and vice versa.

In wind instruments the force with which the wind is blown into the tube helps to get the pitch higher. In percussion instruments the pitch is increased or decreased by tightening or loosening the leather strap. Thus tightening or loosening the drum faces changes the pitch.

3. The frequency of a string kept at constant tension and length, varies inversely with the mass of the string i.e. the greater the thickness of the string, the lesser the pitch or the pitch or the frequency.

Take four strings of the same material and quality but with diameter in the ratio 1:2:3:4. Set them up side by side on a sonometer and stretch them by equal weights. If we pluck them, the thickest will have the frequencies in the ratio of 1:1/2:1/3:1/4 from the thinnest to the thickest. So the thicker the string the lower the pitch.

In wind instruments flutes with thicker walls and those with longer circumference give lower notes and flutes with thinner walls and smaller circumference give higher pitches. In percussion instruments, those with thicker skins will give lower note and those with thinner skins will give higher notes. This is the volume of sound produced. The same note may be produced with varying loudness.

These laws can be mathematically expressed as follows.

If n = the frequency of the fundamental note

L = the length of vibrating segment of string

T = the tension of the string (T = mg)

{ m = mass of the land & g = acceleration due to gravity}

M = Linear density or mass per unit length of the string

i. Tension 'T' and Linear density (M) being constant, the fundamental frequency of the note 'n' is inversely proportional to the length of the string

n is α 1/l (or)

nL = K 1\L where 'K' is a constant (or)

nL = K = constant

ii. 'L' and m being kept constant 'n' is directly proportional to T

n is α $\sqrt{T}$ (or)

$n^2 \alpha$ T (or)

n^2 / T = constant

iii 'L' and 'T' being constant,

'n' is inversely proportional to M

i.e., n 1/M or n^2 M = constant

2. VIBRATIONS OF AIR COLOUMNS

The familiar phenomenon of the sound obtained by blowing across the open end of a key shows that vibrations can be set up in an air column. An air column of definite length has a definite natural period of vibrations. When a vibrating tuning fork is held over a tall glass tube, placed in a cylinder of water into which water is poured gradually, so as to vary the length of the air column, a length can be obtained which will resound loudly to the note of the tuning fork. Hence it is easily proved that the number of vibrations of the air column is the same as that of the tuning fork.

Experiment:

Support a glass tube open at both ends in a vertical position, with its lower end dipping into water contained in a wider cylider. Holdover the upper end of the tube a vibrating tuning fork. Adjust the position of the tube so that the greatest reinforcement of the sound is obtained. Adjust the distance of the air column till we get actually the resonance or sympathetic note. Repeat the adjustments and take the average of the results from the observations. It will be found from the repeated experiments, that the longer the air column the lower the pitch. The resonance of the air column is produced when the pitch of the air column as well as the pitch of the tuning fork becomes identical.

Vibration of air coloumn in a tube open at both ends :

If we think of an air coloumn in a tube open at both ends , and try to imagine the ways in which it can vibrate, we shall readily appreciate that the ends will always be antinodes, since here the air is free to move. Between the antinodes there must be at least one node, and here the air is preserved at rest because, at the ends, the moving air is either moving towards the centre from both ends or away from the centre at both ends. Thus the simplest kind of vibration has a node at the centre and antinodes at the two ends.

This can be mathematically expressed as follows.

Wave length of the simplest kind of vibration is four times the distance from node to antinode = 2 L

where L is the length of the pipe

Vibration of air coloumn in a tube closed at one end :

In this case one end must always be a node, and the other an antinode. The air at the open end willmove in and out alternately, the amplitude of the vibration being greatest at the opening end and diminishing as we approach the closed end.

The distance from node to antinode in this case is L,

the whole length of the pipe. the wave length is therefore = 4L.

3. FREQUENCY AND INTERVAL

The physical state of any sounded note is given in terms of its frequency, which is number of vibrations the sounding body makes in one second.

The frequency is also given in terms of the length of the string that vibrates to produce that note and this is done always in relation to a fundamental note whose frequency is taken to be 1. Frequency described thus is also referred to as 'relative frequency'or 'frequency ratio'. Since the vibrating lengths of different notes are in simple ratio, the frequencies too are related thus. Knowing that the frequencies of vibrations are invrsely proportional the vibrating lengths, we forget about the lengths, and think in terms of frequencies.

For instance, the length of the string sounding the tarasthayi svara sadja is half the length of the string vibrating to produce madhyasthayi sadja. If the length of the string sounding madhyasthayi sadja is take as '1', then its frequency is could be roughly worked out as

$$\frac{1}{L} = \frac{1}{1} = 1$$

The length of string producing tarasthayi sadja would be half of the previous one, in this case being x 1 = . The frequency would be

$$\frac{1}{1/2} = 2$$

Thus the frequency of tarasthayi sadja is 2, assuming the frequency of madhyasthayi sadja is taken as 1.

By measuring the proportional lengths of the string producing the other notes we can compute their frequencies which are given below.

No.	Svarasthana	Frequency Ratio
1	sadja	1

2	suddha-rsabha	16/15
3	catuhsruti-rsabha	9/8
4	sadharana-gandhara	6/5
5	antara-gandhara	5/4
6	suddha-madhyama	4/3
7	prati-madhyama	64/45
8	pancama	3/2
9	suddha-dhaivata	8/5
10	catuhsruti-dhaivata	27/16
11	kaisiki-nisada	9/5
12	kakali-nisada	15/8

Musical Interval

The ratio between the frequencies of two notes is called musical interval. It is equal to or more than one and is never less than one. The interval is computed as the frequency of the higher note divided by the frequency of the lower note or the higher frequency divided by the lower frequency.

For instance the interval between sadja and catuhsruti- rsabha is

$$\frac{9/8}{1} = 9/8$$

Interval between pancama and suddha-madhyama is

$$\frac{3/2}{4/3} = \frac{3}{2} x \frac{3}{4} = \frac{9}{8}$$

4. HARMONICS A musical note may be rendered in a plain or unadorned manner and in a graced or decorated manner according to the raga in which it occurs. On examining the effects produced on the ear by a vibrating string which produces a musical note, in addition to the fundamental note we are aware of a series of higher tones which are called harmonics or upper partials of the fundamental note which is the lowest and loudest of all the tones.

If we strike a string of any instrument provided it is in a proper tension, we can vibrates not only in its entire length but also in parts. What happens is that the string divides itself into 2 or more separate vibrating parts of equal lengths with fixed points called Nodes separating them. All these vibrations are simultaneous and the sounds proceeding there

from are blended into one. It vibrates first in its entire length and then in 2, 3,4, 5 sections etc. The fundamental Sa which is produced by the entire length is the loudest and is called the prime tone, while others are called the upper partials or overtones.

The fundamental tone and the series of upper partial tones which conform to a ratio of 1:2:3:4:5 etc. constitute the **Harmonics**.

For instance, the first upper partial tone is the higher octave of the fundamental sa and makes twice as many vibrations as the prime. The second upper partial tone is the Tarasthayi Pa and makes thrice as many vibrations as the prime. The third upper partial tone is the second higher octave and makes 4 times as many vibrations as the prime tone and it is Atitarasthayi Sadja. The fourth makes 5 times as many vibrations as the prime and it is Atitarasthayi Pa. Thus the relative frequency values of the vibrations which make the harmonic series are related as 1:2:3:4:5:6. Thus while all overtones need not necessarily be part of harmonics series, all harmonics are overtones.

The term 'Svayambhusvara' mentioned in the ancient Samskrta treatises on music correspond to the harmonics.

The timbre or the quality of a musical tone will depend on the number and strength of the overtones.

LESSON -5

1. FREE & FORCED VIBRATIONS

A stretched string when it is struck goes on vibrating till it comes to rest. This vibration natural to itself is called free vibration and the period of its vibrations is called free period. But when this body forces another body whose period is difficult from its own to vibrate then the vibrations of the second body is known as forced vibrations.

Stretch a string between two stands and pluck it. Take a same kind of string and attach it on a sound board and pluck it. The second string will produce a richer and stronger sound. This is due to the fact that the sound board is made to vibrate by the vibrations of the string. Thus the vibrations of the sound board is called forced Vibration and that of the string is free vibration.

2..Sympathetic Vibration or Resonance

It is the phenomenon by which a body is made to vibrate by the vibrations of another body whose frequency is the same as that of the first. The vibration of the former is resonance or sympathetic vibration.

Experiment : Stretch 2 strings A and B on a sonometer. Adjust their lengths by the bridges until the notes heard are in unison. Place a few paper riders on one of them and then pluck the other. The paper riders will begin to flutter vigorously and may be even thrown out. The second string will be going on humming eventhough the first is stopped. But the intensity of the second will be less than that of the first. The rates of vibration will be the same for both. The kind of vibration produced by the first string to influence the second is called the sympathetic vibration.

Sympathetic vibration is - if a string is set in vibration it will cause any other string to vibrate provided the other string is in close proximity and is tuned to the identical pitch or to any one of its upper partials. A very common, phenomenon noticed in the Tambura is that when the Sarani is sounded the anusarani also vibrates, thus helping to produce a louder volume of sound. The sarani here makes the anusarani to vibrate.

Difference between Resonance and Forced vibration.

1. In resonance the frequency of the two sounding bodies is the same while in forced vibrations it is different.

2. In Resonance the vibrations of the second body is more vigorous than in Forced vibrations.

3. Very often the vibrations of the second body may be seen by the naked eye in Resonance where as this is impossible in Forced vibrations.

3. Beats

When two simple tones of nearly thè same frequency are sounded at the same time, we do not hear them as twó tones and instead, we hear a single note which rises and falls in intensity and these alternations in intensities are known as beats and they produce dissonance. That is,, we hear one tone the frequency of which lies between the two and the intensity of which increases and decreases perodically. This periodic waxing and waning is known as beats.

The number of beats heard in one second can be said to be equal to the difference between the frequencies of the notes producing the beats.

The beats will be slow when the difference in frequency is small. But as the difference increases the beats will be produced more rapidly. When they are slow their effect may be moderately pleasing. But when they are rapid it becomes more and more unpleasant. But when they become still more rapid the unpleasantness decreases since it becomes a full next note higher or lower.

Experiment :

Adjust the length of two vibrating strings by a bridge until the notes emitted by them are in unison. Now change the pitch of one of the strings slightly and then sound them together. Beats will be slowly heared. Change the tension of the string still more and see whether the beats are made slowly or more rapidly. If the beats are made slowly that shows the unison is being approached. If it is more rapid, then we are going further from the unison. Then the string should be adjusted in the direction till the beats finally disappear. Thus by listening to the beats we are able to tune the musical instruments accurately.

Experiment:

To show that the number of beats heard per second is the difference between the frequencies -

Consider two tuning forks A and B of very equal frequencies say 240 and 244, which are sounded together. After 1/8th. of second A completes 30

vibrations and B completes 30.5 vibrations. Minimum sound is produced. After 1/4th. of a second A completes 60 vibrations and B complete 61 vibrations. Maximum sound is produced. Thus in 1/4 seconds 1 maximum and 1 minimum are produced. In the full one second 4 maxima and 4 minima are heard. The sound waxes and wanes 4 times per second i.e., 4 beats are heard. Here the difference in frequencies is (244-240) = 4 therefore the number of beats heard per second is the difference between the two frequencies. The same thing happens when the frequencies are, say, 240 and 236.

4. Combination tones

Consider two strong of frequencies X and Y. When they are sounded together it can be shown that by mathematical analysis a series to tones of other frequencies are produced along with the original one. These tones are falled Combinations tones. One should not confuse these combination tones with the harmonics accompanying a fundamental note. Combination tones are classified into two categories.

i. Difference tones   ii. Summation tones.

The famous violinist Tartani was the first to observe this tone. So this tone is called Tartanian tone. It is a very common occurrence and we can find this applied in policeman's whistle. When it is blown the air passes through the mouths of these two pipes of unequal length and the different tone of these 2 pipes when blown together is heard very loudly.

For instance, if there are two tones of frequencies 550 and 320 vibrations per second which are sounded together , then we will hear in one tone of the value 870 (550 + 320) and one of the value 230 (550 - 320). The resulting combination tones would further interact to give more combination tones like 550+230, 320+870, 870-230, and so on. The harmonines of the basic tones will also play part in the combinations tones.

Difference Tones:

The tone of frequency (X-Y) and (Y-X) is called the first difference tone. It is the strongest of the combination tones (X-Y) and Y can produce a difference tone of frequency (X-2Y) This is the second difference tone. Like this infinite number of difference tones of frequencies

(X-Y) (X-2Y) (X-3Y) (X-4Y) ....

or

(Y-X) (Y-2X) ....is theoretically possible.

Summation tones:

In a similar manner one can expect summation tones of frequencies (X+Y) (X+2Y)..........(Y+2X) ....etc. In fact an infinite number of summation tones is also possible theoretically. But only the first difference tone is audible and even that is weaker than the two primary tones. The second third etc., difference tone and summation tones are extremely weak in intensity and therefore not at all audible.

5. Absolute Pitch and Relative Pitch

Absolute pitch is the assigning of a note name to a sound by virtue of frequency in terms of vibration number. For instance, the having a frequency of 440 vibrations per second denotes the note 'A' in the Western music scale. Similarly the other notes like C, D, E, F, G and B have specific frequency value.

A sense of absolute pitch is the capacity to name a note which has been produced without any standard of pitch being previously sounded. It is not the correct judgement of a musical interval - it is assigning a note to its proper place in the musical scale. It has long been known that some people possess this gift, that those who do possess it differ very much in the accuracy of their judgements, and observation have been made suggesting that in some cases at least the accuracy of judgement can be considerabley improved with practice.

Relative pitch, on the other hand, refers to the placing of the first note of a scale on any desired pitch and the remaining notes occupying their corresponding higher pitch positions in relation to the first note. In Indian music, the first note sadja or sa, i.e., the madhyasthayi sa is placed on any desired pitch position or frequency number which would be convenient for a singer or for performing the instrument. In relation to this selected pitch the remaining notes are placed in the proper pitch positions or frequency numbers.

The sense of relative pitch is the capacity to identify a pitch as suddha ri, antara ga etc. when the madhya sa has been sounded in the beginning. Students of music are trained to identify or sing different svarasthanas while the madhya sa is shifted from one basic pitch to another.

6. Just intonation and Equal temperament

Just intonation means intoning or sounding a note just as it is and not assigning it to a pitch artificially conceived for some other purpose or exigency. In Indian music, the plain notes (those which are not oscillatory in nature) are sung naturally governed only by the form of the raga to which they belong.

In the Western system of Classical music this used to be the case until, to overcome the limitations of playing their music on instruments like Piano, the pitch positions of the 12 notes were tempered in such a way that interval of one octave was divided equally between the 12 intervals resulting in 12 equal semitones.

Western music involves 'modulating' from one key to another. The commonest modulation is that from the key of C Major (having a scale approximating to that of our Sankarabharana mela but commencing on the absolute pitch of C) to the key of G Major (same scale but commencing on G). In C Major scale the first interval or first step from C, i.e., C to D is a major tone interval (9/8). But the interval from G to A, the first step in the G Major scale would be 10/9 which is slightly less than 9/8. Thus to make possible the major scale starting from G, we must have a new A which is slightly sharper.

With the human voice, string instruments, and many wind instruments there is no limit set to the number of notes that can be used. with the piano and the organ this is a very different matter. Each one requires a separate lever or key, and the mechanical difficulties in design and execution become very great. To add an extra A and some similar extra notes would become too cumbersome. A compromise is made by which all the intervals are rendered equal so that modulation from one key to another would not pose any problem. Each of the twelve intervals would be of the value approximately 1.06 (53/50). The process of compromise by which true intonation is sacrificed to the exigencies of the mechanics of keyed instruments in order that freedom to modulate may be secured is temperament. There are two methods of temperament - Mean tone temperament and Equal temperament. What has been described above, namely dividing the octave into 12 equal intervals is Equal temperament.

LESSON 6

ACOUSTICS OF THE AUDITORIUM

In an acoustically good concert hall it is not necessary for the musician to exert and make himself pleasing to the listeners. He feels himself confident and his performance will not fall flat as soon as the concert commences. When performances are conducted in open air theatres there is no need to see to the acoustic principles. The sound waves reach the listeners by direct radiation from the performer and they never return as in the case of four walled theatre. Concert halls are usually rectangular in shape.

1. Among the conditions most essential for an auditorium, the most important is the absence of echoes. We have seen that sound travels from the source in a series of compressions and rarifications known as sound waves and they move outwards from the source in expanding spherical waves. They reach the hearers or strike the boundaries of the room in which case the sound is absorbed or reflected.

It is absorbed at a rate depending on the porosity of the various surfaces of the room. In the cases of the surfaces which are not porous, for example, steel and marble, sound echoes and re-echoes. When it comes into contact with such structures with porous surfaces, sound decays more easily and quickly. We find that echoes are not noticeable when the interval between the source and the reflected sound is less than 1/15 of a second. The distance travelled by the sound wave in 1/15 of second is 75 feet. So if the reflecting surface like the backwalls is 37.5 (37) feet away from the singer then the echo will not be separately heard by the ear but it will be only like the continuation of the original sound. When the length of the hall is less than 75 feet the question of echoes does not arise.

In the case of large halls, specially when they are more than 37 feet in length and are of the smooth surfaces, the question of echoes arises. The sound waves in this case after reaching the listeners strike the boundaries and undergo reflection as sound travels at the rate of 1100 ft.per second. The waves are reflected not once but many times before they disappear. The numerous reflections make unequal intensities in the sound heard in the different parts of the auditorium. It is therefore important that such reflecting surfaces should be made absorbent suitably broken up so that the sound is no longer reflected but is enfeebled.

Scattered echoes are also produced by high ceilings rectangular or curved. If a curved ceiling is preferred, its radius of curvature should not be less than twice the height of the wall so that the sound waves on being reflected may not meet inside the hall and make echoes. If the curved surfaces are present in the auditorium the echoes will be magnified at the places near the focus.

2. Secondly the loudness should be adequate and uniform throughout the building. The listeners should not be less than 50 yards away and they should have a direct view of the singer so that they can receive an uninterrupted ray of sound. Sometimes dead spots may be noticed in an auditorium. At these places the direct sound waves and reflected sound waves interfere and destroy one another with the result that no sound is heard at all by the listeners. These surfaces which give rise to dead spots are covered by absorbents to enfeeble the reflected waves.

3. Another phenomenon that should be avoided in constructing an audiotorium is undue reverberation. It has been long recognised that this is the most frequent defect found in large area. This undue persistance of sound is due to insufficient absorption by the boundaries. A little reverberation is pleasant and helpful to both the performer and the listener but excess causes confusion and overlapping of successive sounds. The audience failsto analyse the pure sound. This is called undue reverberation. We can notice this in high walled temples and empty houses. This reverberation vanishes as soon as the room is filled with objects such as carpets, furniture etc.

4. Another point to be kept in mind is that the hall should be responsive to musical sounds of all pitches and should be devoid of marked resonance. Such resonance may assist the sounds but its effects are limited to sounds with in a restricted range of pitch. It will necessarily end in the distortion and modification of music containing such notes. What happens is that certain structures in the hall being resonant to certain notes sound louder than others. In an ideal auditorium steps should be taken to control such resonances.

5. Finally the walls should be sound proof. The atmosphere will be filled with sounds varying in pitches with sustained notes rich in harmonics. A noteworthy result is that the fundamental note will be heard at one point and a overtone equally closer to it at another. It is an unhappy interference of outward sound with the sounds of the interior clashing together. Sometimes it becomes louder and higher and

practically drowns the sound of the concert. It is difficult for the singer to concentrate.

Characteristics of a good hall:

1. Absence of outside disturbances : The place should be isolated from public roads, trafic, schools and hospitals. Thick walls will help to avoid outside disturbances.

2. Absence of echoes : Curved ceilings produce more echoes and curved walls easily produce echoes. Height of the ceiling should not be more than that of the walls. Irregularity of walls will help to prevent echoes. Porous substances can be used as absorbers.

3. Adequate loudness : Every one should hear good sound. Sound should be uniform through out the hall. The musicians voice will reach about 50 yards in front, 30 yards to the sides and 20 yards behind. Microphone arrangements and Microphone horns in open air also help to produce adequate sound.

4. Undue reverberation : It means undue persistance of sound. Large halls reverberate a lot and echoes and re-echoes will form. If there are very few people there will be more reverberation. If there are more people their bodies absorb some of the sound. Little reverberation gives pleasing sound but more reverberation creates confusion. Screens, Cushions, Bricks and Ceiling create reverberation. Celotex boards are used to control reverberation. certain plasters are also used to control reverberation.

5. Avoiding marked resonance : In marked resonance some particular notes alone will be heard loudly. The hall should reverberate all notes.

6. Avoiding outer sound from entering the hall : Sound from outside should not enter the hall and the sound from the hall should not leak outside, i.e., the hall should be sound proof. If sound leaks outside there will be scattering of sound. If the hall is not sound proof we hear upper partials. To correct these defects double walls or thick walls could be built round the hall. Above all the location of the site for building the wall is very important. The location should be away from such sources of disturbance as factories, schools and colleges, bazaars and busy roads, carrying heavy vehicle traffic.

LESSON No - 7

THE ROLE OF RADIO AND GRAMAPHONE

Nowadays it is very common to see people carrying with them transistor radios and tape recorders whereover they go. They record the programmes of their liking and replay them to listen at their leisure. All India Radio arranges to record special programmes conducted by sabhas and at temple festivals and broadcast them from the studios at later dates. A.I.R. also keeps a "Record library" where records of many eminent speeches of talented speakers, musical discourses of eminent artists etc are stored. This provides an opportunity for the artists of younger generation to listen to the performances of artists of earlier generation. There are some more advantages. It is not necessary for the artists to present themselves at the studios at the time scheduled for broadcast. Their programmes can be recorded earlier and broadcast on that particular day. Even some small flaws that may creep in during direct broadcast can be rectifed during recording.

Similarly only after the invention of recording sound on the cinema film itself, talking films became famous.

So our curiosity is now to know how the sound or music is recorded and reproduced.

1. RECORDING

Disc Recording

The first recording and reproduction device was edison's phonorgaph. Many improvements were made by scientists like Dr. J.G.M. kendrick and finally in 1894, the Berliner machine was invented and in it the record was made on a disc.

Record Making: Preparation of the Original

A soft disc of wax is placed on the recording instrument and a controlled needle is adjusted in position on this recording disc. When no sound is recorded, the needle takes a spiral path moving towards the centre of the disc. When sound is recorded, the needls moves from side to side and takes a wavy apiral path instead of a smooth one. Now the disc with the pattern marked is called the original. A number of such originals is prepared and the best of the lot is selected.

Preparation of Positive or mother shell:

A very thin layer of graphite is coated on this selected original to make it conducting. This is put in the cathode and a copper plate in the anode of a copper voltameter and a suitable current is passed. Copper is deposited on the mould faithfully reproducing every detail of the trace on the wax. The shell thus got is called the negative. It is now treated by a speical process and again placed in another electroplating bath. Copper is deposited as before on its surface and when sufficent thickness of copper is deposited it is removed from the negative shell and the result is a positive record. This can reproduce the exact form of the original wax and can be played with a fibre needle.

Preparation of actual record discs:

From the positive a number of negative shells known as working matrix is prepared. If the record is on both the sides, working matrix both for upper and lower sides are prepared.

The record material, prepared to required plasticity is placed in position over the central pin of the working matrix. and hydraulic pressure is applied. The plates are sufficiently cooled by flow of cold water through them. This record is then removed and its edges are polished. Now it is ready for use.

Reproduction:

The record is revolved by the slow release of a wound-over spring and the needle placed on it moves faithfully and vibrates the diaphragm of the sound box and the sound is heard. Nowadays for recording, sound energy is converted into electric currents and the needle is moved according to the vibrations of the current (current variations converted into mechanical variations). While reproducing, the mechanical variations are converted as electrical variations. These electrical variatioons are fed into a loudspeaker from which sound is heard.

Tape recording

The magnetic property (attraction of ferromagnetic substances by an eletromagnet) is the basic principle involved in tape recoding. The magnetic tape behaves as a magnet made up of very tiny magnets (Iron oxide crystal acts as a tiny magnet). The tape used is usually made of "cellulose acetate" or Poly Vinyl Chloride (PVC). It is thin so that

maximum length can be wound on a reel. The material of the tape must be flexible but should not stretch itself under tension. Tapes are also made from a kind of terelyne called "MYLAR"

Principle of recording:

One side (dull side) of the tape is coated with a paste of ferric oxide containing needle shaped iron oxide crystals. These crystals can be imagined to be similar to magnetic compass needles, each having north and south polarity. In an unrecorded tape, the needles (crystals) point in such directions that the resultant magnetic effect is zero. So, the tape is not a magnetised one. When this is moved in front of an electromagent, the magnetic needles are deflected and the magnitude of delfection depends upon the strength of the magnetic field. After this turning or orientation the needles remain in the new position. Now the tape behaves as a magnet magnetised differently at different positions of the tape. Since the retentivity (retaining power of magnetism) for ferric oxide is large the recorded tape serve as a permanent record.

How does actual recording take place?

When a person speaks or sings before a microphone the sound vibrations are converted into varying electric current impulses. These electrical variations after due amplification are fed into the electromagnet which in turn produces corresponding variations in the magnetic field strength. The tape is run in such a way that the dull side faces the gap. The magnetic needles (cyrstals) get oriented according to the variations of strength of magnetic field. Thus sound is recorded on the tape as magnetic variations.

Reproduction:

Reproduction is exactly the same as the recording process in the reverse direction. The recorded tape is allowed to run near the gap of the play back head. The magnetic variations on the recorded tape make corresponding variations in the magnetic field of the electromagnet. The varying magnetic field produces a varying electric current in the coil wound around the play back head. These varying electric signals are amplified and fed into a loud speaker. The original recorded sound is heard

Note on erasing the tape:

Whenever new recording has to be made on a tape, it is essential that the recording is completely erased. The erasing of a tape is done by passing it before an erasing head. This erasing head consists of an electro magnet which is fed with a strong current of very high frequency such as 50 Kilo-Hertz. This rapidly varying strong current completely neutralises the previous recorded pattern and the tape is ready for a fresh recording.

2. BROADCASTING

The technical problems involved in broadcast transmission and reception may be summarised as follows:

to convert the sound waves of the programme into electric impulses or currents, each characteristic of the sound itself,

to convey these impulses without distortion to a radio transmitting station,

to superimpose them on the electromagnetic waves being radiated so that they are diffused into space,

to pick the waves up again at a distant point and to separate the electrical impulses form them in their original form,

to increase them in magnitude in order to compensate for the losses during transmission, and finally,

to reconvert the impulses into sound waves of a similar nature to those originally produced.

Sound waves are set up in the air in the broadcast studio when any "noise" - musical or otherwise - is made, these air disturbances travelling outward from their source at approximately 1100 feet per second. The character of a sound wave varies in accordance with a number of factors, one of which is its "frequency". If the number of air vibrations per second is large, the "pitch" of the note is high, while if it is small a low note is produced. The lowest note of a piano, for example, has a frequency of 27.5 cycles per second, and its highest note about 5600 cycles per second. The range of frequencies which the average person can appreciate is from about 20 to 16,000 cycles per second.

A second feature possessed by a sound is its "loudness" which depends upon the intensity of the sound waves produced, while a third and more

subtle characteristic is the "sound quality". It is this which enables us to distinguish between two sounds of the same pitch and loudness, and to recognise, from the distinctive quality, to which instrument of the orchestra each owes its origin. This quality of a sound is due to the fact that it consists, not of a single frequency, but of a mixture of one "fundamental" frequency and several "harmonics". The proportion in which these harmonics are present determines the musical or "timbre" of a note or sound.

In broadcasting the aim is to transmit all these features of the sounds without distortion. Although this cannot be done perfectly - because the apparatus is unable to handle the full ranges of frequency or loudness — good-quality transmission can be achieved if frequencies from about 30 to 10,000 cycles per second, and a loudness range covering all but the weakest and most intense sounds , are provided for.

Broadcasting studios are rooms designed to suit a particular type and size pf programme, the walls — which both reflect and absorb the sound waves— being constructed or treated so as to give that quality to the sounds most desirable and pleasing for the particular type and size of programme, the walls— which both reflect and absorb the sound waves— being constructed or treated so as to give that quality to the sounds most desirable and pleasing for the particular type of programme. In addition, there are "General Purpose" studios , whose acoustic characteristics can be varied to suit the programme requirements.

Adjacent to the studio there is usually a listening-room, sound insulated from the studio, in which the programme can be heard from a loudspeaker, so that it may be judged as it will sound in a listener's home, as distinct from what it sounds like in the studio. Sometimes it is necessary to add "echo" to the programme, i.e., to give an effect such as would be produced in the interior of a cathedral. This is achieved by taking part of the studio output to a loudspeaker in an "echoroom". The sound from this goes echoing round the bare walls of the room, and the result - containing the echo- is picked up by microphone, and may then be added to the original programme.

Each studio contains one or perhaps several micophones, according to the purpose for which it its used, these being the devices which convert the sound waves into electrical impuses.The type of micrphone in most common use to-day is the "ribbon" type, in which a strip of aluminium

foil is suspended within a strong magnetic field. Any movement of a conductor in a magnetic field causes an electrical voltage to be set up in the conductor,and when the "ribbon" vibates under the impact of the sound waves, electrical votages or impulses are set up in it which are faithfully representative of the sounds which caused them. The outputs from several microphones may be mixed in any desired proportion by means of a simple electrical arrangement in the listening-room, and the combined output is then taken to the control room of the broadcasting centre.

The control room is the electrical "nerve centre" of the whole system, and through it all the progammes pass. It contains "amplifiers" to which the studio outputs are connected, "mixers" for combining, when necessary, the outputs of several studios or other progamme souces, and switching arrangements and "fade units" for maintaining the continuity of the progamme. The equipment is followed by the main control amplifier and the control potentiometer, by means of which the intensity of the electrical impluses is kept within the range that can be handled by subsequent apparatus. Finally, there are the amplifiers which tranfer the progaramme to the lines conecting the control room to the radio transmitters.

Radio transmitters :

The first function of a radio transmitter is to generate high-frequency oscillations which, when amplified and fed to an aerial system, will set up electromagnetic waves in space. Its second function is to provide some means of "modulating" these waves so that they will carry the intelligence which it is desired to transmit.

The transmitter may operate upon wave length varying from several thousand metres to a few centimetres (i.e., the frequency of the oscillations it produces may vary from a few thousands cycles to hundreds of millions of cycles per seconds) according to the purpose for which it is intended. The form of intelligence transmitted may also vary widely, ranging from telegraph to broadcast speech and music or television.

If a coil of wire is connected in the anode circuit of a valve, and another coil in the grid curcuit , the valve can, by means of the electrical inter action between these coils, be made to produce electrical oscillations by choosing particular values of "inductance" and "capacity" in these

circuits the oscillations can be "tuned" to the desired frequency. The "inductance" usually consists of suitably proportioned coils of wire, while the "capacity" is provided by means of "condensers", which consists of sheets of metal separated by air or some other insulating meterial. The oscillations which are produced by this "drive" circuit (as it is called) are then passed through as many "amplifying" stages as are necessary to increase the power to the level suitable for applying to the aerial. Such oscillations when radiated by the ariel do not themselves convey any intelligence, and the resultant wave is called the "carrier" wave.

To impart the intelligence to the carrier it is necessary to "modulate" this wave with, for example, a broadcast programme. This as we have seen, is composed of electrical impulses which vary in accordance with the sounds which produce them. Like the output of the "drive" circuit, the programme signal received over the lines from the studio or amplified until they are of sufficient power to be applied to the modulator valve or modulation transformer, according to the system in use in the particular transmitter. By one of these means these amplified programme currents are made to alter the "amplitude" of the oscillilations of the carrier wave. The result is that while the frequency of the carrier wave is uneffected its amplitude

varies in sympathy with the programme impulses it is carrying. The programme impulses are therefore conveyed through space to the receiver, and at the receiver it is only necessary to cause the variations in the amplitude of the received wave to set up electric currents, and these will be an exact replica of those produced by the microphone.

The method described above is only one way of modulating a carrier wave; another, known as "frequency modulation" (F.M.for short) although more complex has certain advantages which are likely to render its use fairly wide spread in the not very distant future.

In this system (F.M.) the amplitude of the carrier wave remains unchanged, and its frequency is varied at a rate corresponding with that of the programme. Until fairly recently frequency modulation had not been used to any great extent, chiefly on account of the more complicated apparatus necessary. Under suitable conditions, however at transmitter using this system can offer improved fidelity, greater freedom from interference, and the larger broadcast service area than a comparable amplitude- modulated transmitter.

Aerials :

The function of the aerial is to place the high-frequency oscillations generated in the transmitter in contact with as great a volume of space as possible, so as to permit a relatively large radiation of energy into space. Conversely, a receiving aerial, because it is in contact with a comparatively large volume of space, can absorb a larger amount of energy from the passing wave than the receiver circuits themselves . All radio receivers - except those fitted with a built-in "frame" aerial- should therfore be connected to an efficient aerial in order to obtain the best results.

Radio Receivers :

Although the broadcast receiver is only one of the many types of radio-receiver equipment in everyday use, the general principles underlying its operation area common to all radio- receiving apparatus.

As stated earlier, its main functions are to accept the energy picked up by the aerial from the passing radio waves; to separate the low frequency programme impulses from the high frequency carrier wave, and, having separated them, to amplify these programme impulses to a power level sufficient to operate the subsequent apparatus, usually a loudspeaker, for reconversion into sound.

3. TELECASTING

Television is the electrical transmission of visual images. This system can transmit video signal along with sound waves.

General principle:

In this system the optical image is converted into electrical signal. This electrical signal is stored in a photo sensitive plate, contained in a camera tube. Then it is scanned by an electron beam. The scanning process breaks the electrical images into individual picture element producing a video signal. The video signal, after amplification is transmitted along with audio signal.

At the receiving station, both audio and video signals are recieved and they are separated by a director. The audio signal after amplification and detection is fed into the speaker. the video signal is applied to CR tube for image re-production.

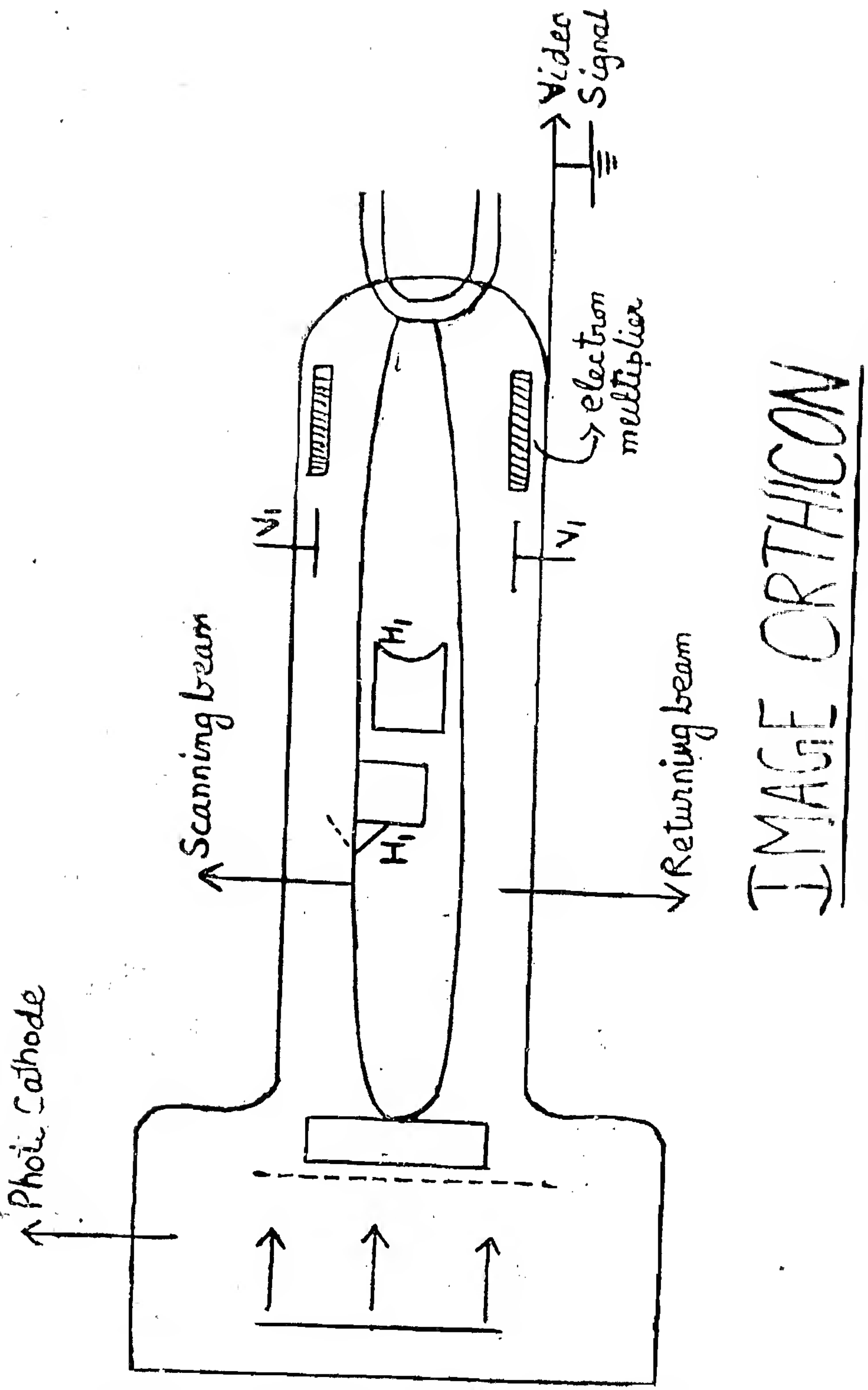


Image orthicon:

The image orthicon is a very sensitive TV camera. The structure is as shown in figure. It has an image section at one end, and an electron gun and an electron multiplier at the other end, deflecting and focusing coils are fixed at the Middle. Here V1V1 and H1H1 represents the vertical and horizontal coils.

A current through this coils produces a magnetic field which deflects the electron beam from the normal course. The image section has a photo sensitive plate, called photo cathode. It is kept at a high positive potential. It is done so that the electrons are emitted from its back side in proportion to the light intensity falling on its front side. A screen having 400 meshes per cm. and a target are kept at the other end of the image section.

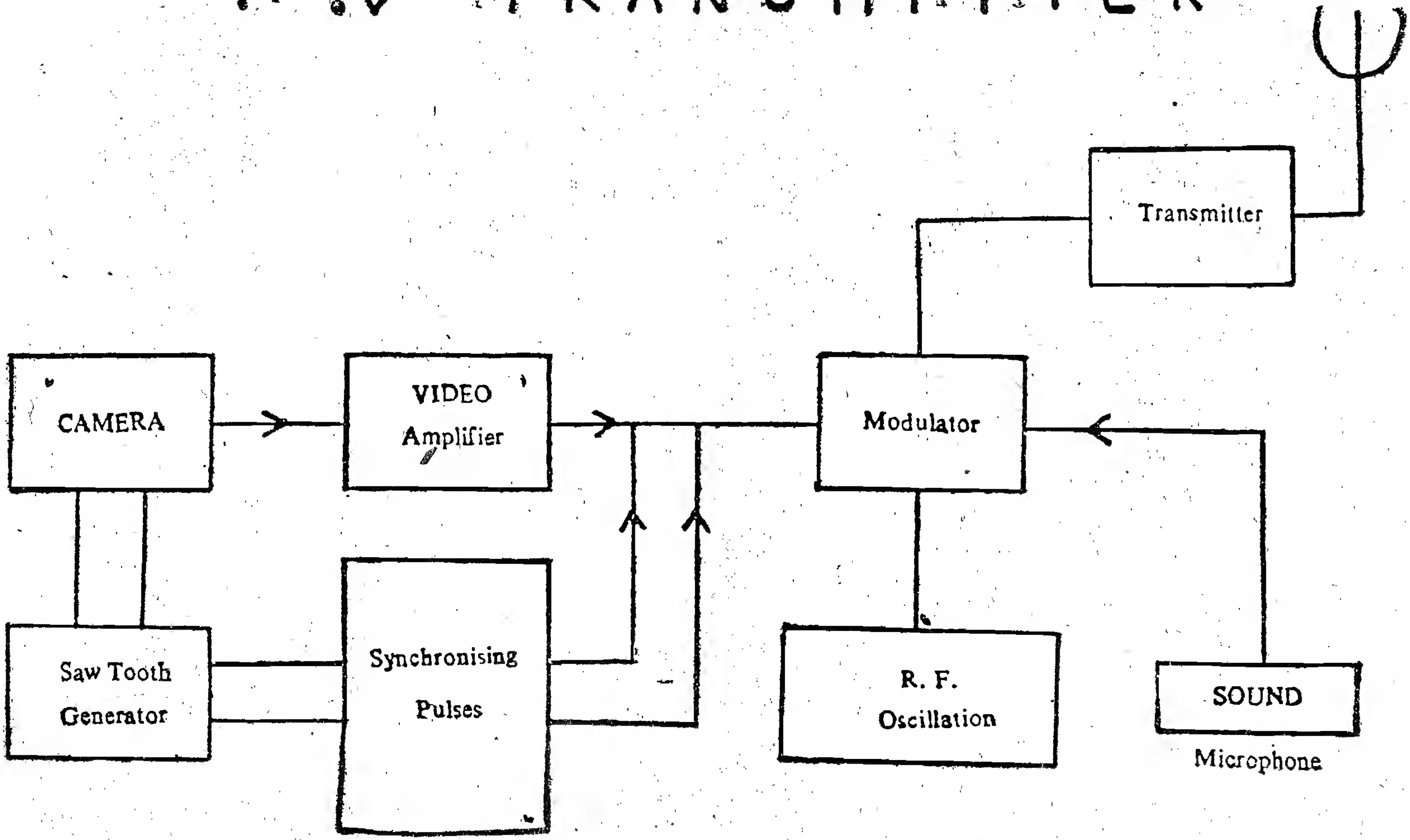
When an optical image of the object is focused onto the photo plate, photo electrons are emitted from its back side. Most of the electrons pass through the meshes of the screen and strike the target. As a result secondary electrons are emitted form the target. These secondary electrons are drawn to the screen. The target is left with the positive charge corresponding to the optical image of the object. Then the target is scanned by an electron beam. The beam deposits electrons at each point on the target to neutralize the positive charge. The remaining electrons in the electron beam returns to the electron gun.

The electron density of the returning beam varies in accordance with the positive charge distribution on the target. The returning beam strikes the aperture of the electron gun. So the electron gun emits secondary electrons and these secondary electrons are deflected in a eletron multiplier system whose output is the amplified reproduction of the returning beam. Thus a video corresponding to the object is available across the Load resistor.

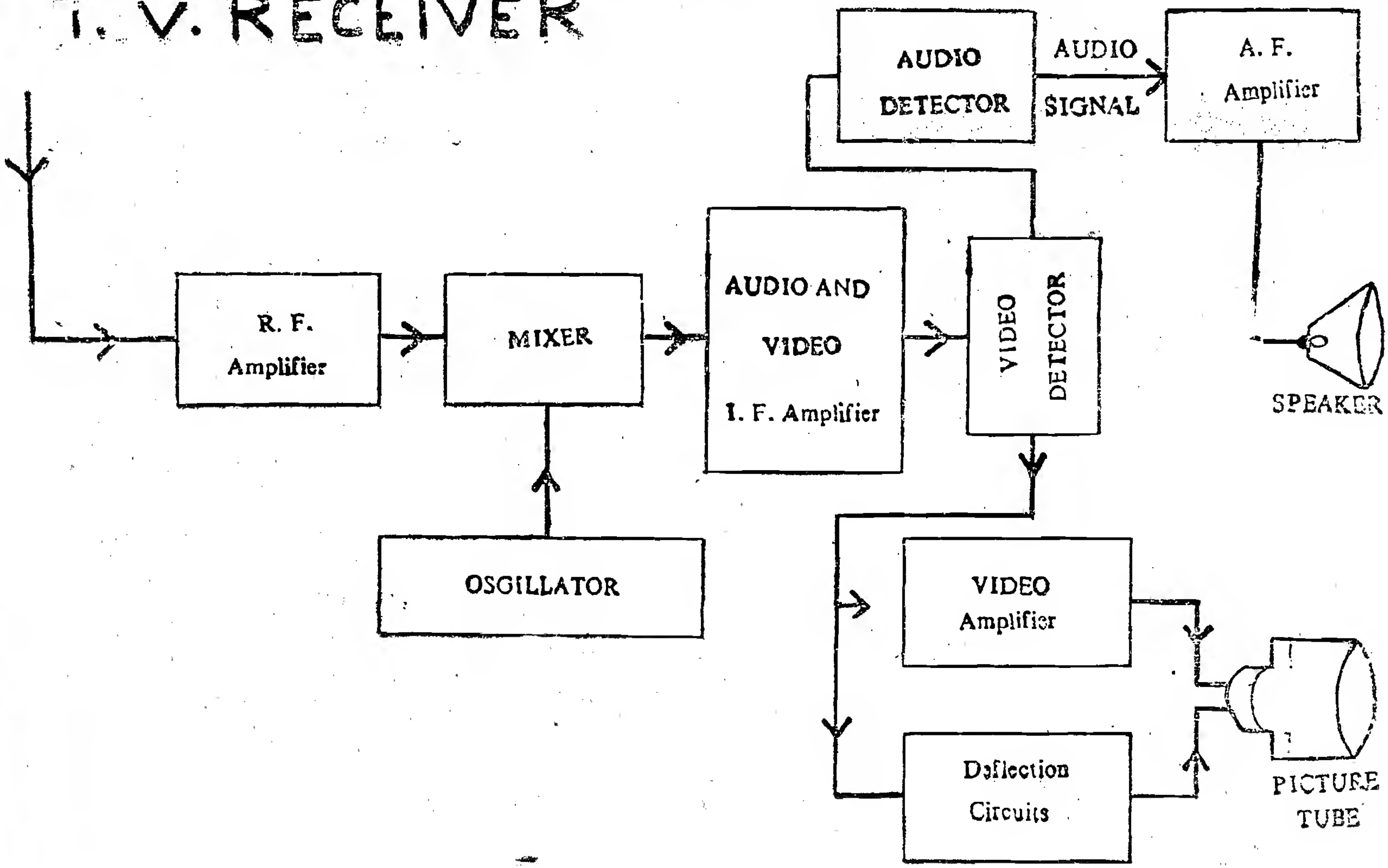
Scanning:

For good transmission and reception, the electron beam should scan the target in an orderly fashion. In the scanning process. the electrical picture of the optical object is divided into number of small individual picture element. In the transmitted system, the electron beam scans the target from left to right and from top to bottom by means of the coils H1H1 and V1V1.

T. V TRANSMITTER



T. V. RECEIVER



AUDIO DETECTOR
AUDIO SIGNAL
A. F. Amplifier
R. F. Amplifier
MIXER
AUDIO AND VIDEO I. F. Amplifier
VIDEO DETECTOR
SPEAKER
OSCILLATOR
VIDEO Amplifier
Deflection Circuits
PICTURE TUBE

In horizontal scanning the spot moves from left to right and at the end of each line the spot returns to the left. The return is made very quick and during this time the camera is blanked out. Similarly at the end of bottom right side corner of the image, the beam returns to the top of the left side corner of the image. During this time the camera is blanked out. The process is repeated. The target consists of 406 lines, the top and botton are half lines. The scanning is done in two operations. First by adjusting the Horizontal field, the sport moves from left to right of the 1st line.

At the end, the horizontal sweep circuit beings the spot down to the third line. Now the third line is scanned. Similarly the fifth, seventh, ninth........... four hundred and fifth (405th.)lines are scanned. Then odd numbered lines are scanned first. Now the vertical circuit brought the spot to the top and the horizontal ciricuit to the left of the second line. Now the even numbered the lines are scanned and along with this a single complete scanning is over. Each complete operation takes place in 1/25th. of a second.

Along with video signal, audio signals with frequency modulated is also transmitted. In the recieving station they are separated. The audio signal after amplification and detection is amplified to a speaker. The video signal is amplified and applied to the control grid of the receiver which is nothing but a CRO. The scanning in the receiver is in step with that in the transmitter and so the final picture is produced on the screen with great stability and sensitivity. The operation of the transmitter and receiver can be illustrated by the following block dagram 1&2.

LESSON - 8

1. CYCLE OF FIFTHS & FOURTHS

Introduction:

In the theory course of the first year we became familiar with the concept of samvaditva. We have seen how sadja and pancama are considered samvadi and similarly sadja and suddha- madhyama interval being termed samvadi. The relationship between these notes will be seen as:-

a) the first to the fifth:

sa	ri	ga	ma	pa
1	2	3	4	5

b) the fifth to its fourth:

pa	da	ni	sa
1	2	3	4

It is obvious that this relationship between pañcama and tara sadja is the same as sadja to madhyama:

pa	da	ni	si
sa	ri	ga	ma

Hence the interval of a fourth is an inversion of the fifth. These relationships, namely sa-pa and sa-ma are called samvaditva. When sounded together these sets of svaras produce a perfect coalescance, as there is natural smoothness in the relationship of fifths and fourths. When vivadi svaras are sounded together, they fail to produce this pleasing effect, i.e. they do not merge together in coalesence to bring about the consonances between them.

Cycle of fifths and fourths:

The process of cycle of fifths is the successive relationship created from a svara to its fifth or in other words, going up in a series with a landing on every eighth step.

S 1	R 2		G 3		M 5		P 5
S 1	R_1 2	R_2 3	G_1 4	G_2 5	M_1 6	M_2 7	8

Similarly the cycle of fourths is got with the successive relationship created from a svara to its fourth:

<table>
<tr><td rowspan="2">S
1
S
1</td><td colspan="2">R
2</td><td colspan="2">G
3</td><td>M
5</td></tr>
<tr><td>R1
2</td><td>R2
3</td><td>G1
4</td><td>G2
5</td><td>6</td></tr>
</table>

In the cycle of fifths the first is from sa to pa. In the second step starting from pa and proceeding to the fifth, which should be its pa if pa were to be taken as sa, we arrive at the note ri of the next octave. Thus the series goes on and at the twelth step, we come back to sadja of the eighth octave. In the cycle of fourths, the proceeding the similiar manner, we come to sadja of the sixth octave.

The following tables give the svaras obtained in the successive steps of the cycle of fifths and fourths:

Cycle of fifths

Step					Octave
1	S	-	P	-	1
2	P	-	R2	-	2
3	R2	-	D2	-	"
4	D2	-	G2	-	3
5	G2	-	N2	-	"
6	N2	-	M2	-	4
7	M2	-	R1	-	5
8	R1	-	D1	-	"
9	D1	-	G1	-	6
10	G1	-	N1	-	"
11	N1	-	M1	-	7
12	M1	-	S	-	8

Cycle of fourths

Step					octave
1	S	-	M	-	1
2	M	-	N1	-	"
3	N1	-	G1	-	2
4	G1	-	D1	-	"
5	D1	-	R1	-	3
6	R1	-	M2	-	"
7	M2	-	N2	-	"
8	N2	-	G2	-	4
9	G2	-	D2	-	"
10	D2	-	R2	-	5
11	R2	-	P	-	"
12	P	-	S	-	6

Though sadja is re-established in the twelfth step, it would be found that it is not in union with the original sadja. Mathematically proceeding, calculating the frequently values of the svaras, the final sadja arrived in the sa-pa series will be slightly more than the original and in the sa-ma series, it would be slightly less. So actually while marking the octaves, the final sadja in the sa-ma series will come under the fifth octave only.

Another point that is to be noted about the Cycles of fiths and fourths is that that the two are mutually complementary. That is, if we commence the cycle of fifth in the downward direction by going to into notes lower than for instance. we find that we arrive at the same notes that we would if we were to do a cycle of fourth proceed in an upward direction.

For instance, if we start from madhya sa and proceed a fifth downwards we arrive on suddha-ma (mandrasthayi). Cycle of fourth from madhya sa in an upward direction would take us to suddha-ma (madhyasthayi). Though the two notes differ by an octave for the purposes of note identification they are the same.

Similarly a cycle of fourth in the downward direction would amount to a cycle of fifth in the upward direction.

2. 22 SRUTI-S AND THEIR DERIVATION

The word sruti is derived from the root 'sru' to hear sruti means that which is heard. The term has been used in the ancient times as a unit for measuring the intervals between two svara-s. A sruti is the smallest interval discernible by an average musically trained ear. With that a bigger interval, say between a svara position and the next svara position was sought to be measured. If, for example, the interval between a svara X and svara Y was measured to be of 4 sruti-s, then it meant that after the sound of X, there could be sound-1 after an interval of one sruti, sound-2 after the second sruti, sound-3 after the third sruti and finally the svara position Y after the fourth sruti. The sruti values between the seven svara-s when totaled together gave a number 22. The 22 pitch positions discerned through the 22 sruti-s were also called sruti-s and were also demonstrated in the ancient times.

In the present day system the sruti has been sometimes used as a unit for measuring the intervals between the 12 svarasthana- s. And sometimes measurements have been done in terms precise physical measures like vibration numbers and the relative frequencies or their logarthmic savart/cent counterpart units. Attempts have also been made to draw equivalences between the rough measure like a sruti and the precise measures like the mathematical values.

Further the 22 positions demarcated by sruti have been assigned mathematical relative frequency values and have also been regarded as the variety of pitch postions of the seven svara-s. Thus the 12 svarasthana variety got expanded into one of 22, at least theoretically, since the 72 mela system still works only on the basis of 12 svarasthana-s. Due to this process of expansion,

a. sa and pa continued to have only one position each

b. ri and ga shared eight positions now, as compared to the four they shared in the 12 svarasthana system. Similarly dha and ni too shared eight positions among themselves.

c. ma, now had four positions.

The 22 sruti-s or literally, the 22 svara positions were given individual names and expressed in terms of mathematical values. These 22 positions were also identified among the plain note positions met with in the different raga-s.

Chart giving the nomenclature of the 22 srutis with their values and examples found in the some ragas.

Sruti no.	Svarasthana name	Symbol	Rel. Freqn.	Raga
1	sadja	sa	1	all ragas
2	eka sruti rsabha	ri1	256/243	gaula, saveri
3	dvisruti rsabaha	ri2	16/15	pádi, máyamálavagaula
4	trisruti rsabha	ri3	10/9	bhairavi, madhyamávati
5	catuhsruti rsabha	ri4	9/8	sankarábharana kharaharapriya
6	kómala sádhárana gándhára	ga1	32/27	srfrága, bhairavi
7	sádhárana gándhára	ga2	6/5	kápi subhapantuvaráli
8	antara gándhára	ga3	5/4	sankarábharana kámbhoji
9	cyuta-madhyama gándhára	ga4	81/64	dévagándhári saurástra
10	suddha madhyama	ma1	4/3	sríranjani kuntalavaráli
11	tívra suddha madhyama	ma2	27/20	bégada, gaulipantu
12	prati madhyama	ma3	45/32	kalyáni, vácaspati
13	cyuta-pancama madhyama	ma4	729/512; 64/65	varáli hémavati
14	pañcama	pa	3/2	all ragas except pañcama varja
15	ekasruti dhaivata	dha1	128/81	tódi, sáveri
16	dvisruti dhaivata	dha2	8/5	bhúpála, lalita
17	trisruti dhaivata	dha3	5/3	kambhóji

18	catuhsruti dhaitvata	dha4	27/16	vasanta, kannada
19	kómala kaisika nisáda	ni1	16/9	bhairavi dévamanóhari
20	kaisika nisáda	ni2	9/5	dhanyási, ahiri
21	kakalí nisáda	ni3	15/8	sankarábharana hamasadhavani
22	cyuta-sadja nisáda	ni4	243/128	kuranji nílámbari

We note that eventhough Sruti when taken as the number of the pitch position or as a rough measure, as done in the ancient times, would be uniformly equal, when expressed in mathematical terms as relative frequency values, the intervals between two successive postions are not of uniform value.

For instance, the interval between -

$$\text{sa and } ri_1 = \frac{256}{243} \div 1 = 256/243$$

$$ri_1 \text{ and } ri_2 = \frac{16}{15} \div \frac{256}{243} = 81/80$$

$$ri_2 \text{ and } ri_3 = \frac{10}{9} \div \frac{16}{15} = 25/24$$

$$ri_3 \text{ and } ri_4 = \frac{9}{8} \div \frac{10}{9} = 81/80$$

In the recent times the scholars have named these differring sizes of intervals as varieties of eka-sruti-s.

81/80 = pramána-sruti, also known as 'comma'
25/24 = nyúna-sruti, also known as
256/243 = púrna-sruti, also known as 'limma'

In the last 150 years, scholars devised a method of deriving the above mentioned relative frequency values of 22 sruti-s or note-positions by the Cycle of Fifths and Fourths. This would be described now. And as mentioned earlier a cycle of fifth in the downward direction would be similar to a cycle of fourth in the upward direction and vice-versa. This could be mathematically illustrated thus.

Assuming the relative frequency of sa as 1 we would get the value of the note a fifth downward as the frequency of sa (1) divided by the interval of fifth (3/2),

f of sa/ I of 5th. = 1 ÷ 3/2 = 1 X 2/3 = 2/3.

2/3 is the frequency of a note in mandrasthayi because the value is less than 1 [all the notes in madhyasthayi will have the values equal to 1 or greater than () 1 and less than () 2].

To identify the note we should import it to madhyasthayi. This is done by shifting it higher by an interval of one octave, i.e., lower frequency multiplied by interval to get the higher frequency - 2/3 multiplied by 2 (interval of on octave).

2/3 X 2 = 4/3.

We know 4/3 as the relative frequency value of suddha- madhyama.

Now a cycle of fourth in upward direction starting from sa would be frequency of sa (1) multiplied by interval of 4th.(4/3).

1 X 4/3 = 4/3 - suddha-madhyama.

Thus we see that a cycle of fifth in an downward direction is similar to a cycle of fourth in an upward direction.

We now take up the derivation of the 22 values by Cycle of fifth (and fourth).

CYCLE OF FIFTH :

1. First note is sa, whose value is assumed to be 1.
2. The second value is got by multiplying the frequency of sa (1) by the value of the interval of 5th.(3/2)
   1 X 3/2 = 3/2 - pa
3. We proceed in a similar manner for getting the value of the other notes, now starting with the value of the last note obtained and multiplying it with the value of the interval of 5th.(3/2).

$$\frac{3}{2} \times \frac{3}{2} = \frac{9}{4}$$

9/4 is the value of a note in the tarasthayi. To identify it should be brought to madhyasthayi by dividing it by the value of the interval of an octave (2).

$\frac{9}{4} \div 2 = \frac{9}{4} \times \frac{1}{2} = \frac{9}{8}$ - ri4

4. Now the next step should strictly start from 9/4, the last value obtained, but avoid unnecessary transformation of octaves, we may continue with the value obtained in madhyasthayi, namely, 9/8.
   9/8 X 3/2 = 27/16 - dha4
5. 27/16 X 3/2 = 81/32
   81/32 X 3/2 = 81/64 - ga4
6. 81/64 X 3/2 = 243/128 - ni4
7. 243/128 X 3/2 = 729/256
   729/256 X 2 = 729/512 - ma4

Now proceeding from 729/512 will take us to very big fractions and we would not be able to obtain the remaining values among the 22, that we are trying to derive. Hence we abandon the value 729/512 and instead take the value 64/45 which is very close to 729/512.

[729/512 = 1.4238 64/45 = 1.4222]
64/45 - ma4

8. 64/45 X 3/2 = 32/15
   32/152=32/15 X 1/2 = 16/15 - ri2
9. 16/15 X 3/2 = 8/5 - dha2
10. 8/5 X 3/2 = 12/5
    12/52=12/5 X 1/2 = 6/5 - ga2
11. 6/5 X 3/2 = 9/5 - ni2
12. 9/5 X 3/2 = 27/10
    27/102 · 27/10 X 1/2 = 27/20 = ma2
13. 27/20 X 3/2 = 81/40
    81/402 - 81/40 X 1/2 - 81/80 - sa & 1

At this stage we reach the value which represents a note which is slightly higher than sa and slightly less than ekasruti ri. Further continuance of this cycle would only yield the same notes pa, ri4 etc. except they would be slightly greater than their previous values, i.e., greater by an interval of 81/80.

So this cycle has to be stopped at this stage and we move on to the Cycle of Fourth or Cycle of downward fifth.

CYCLE OF FOURTH

1. We start again with sa with its assumed value as 1
2. The second value is attained by multiplying the frequency of sa (1) by the value of the interval of fourth (4/3)
   1 X 4/3 = 4/3 - ma1
3. 4/3 X 4/3 = 16/9 - ni1
4. 16/9 X 4/3 = 64/27
   64/272=64/27 X 1/2=32/27 - ga1
5. 32/27 X 4/3 = 128/81 - dha1
6. 128/81 X 4/3 = 512/243
   512/2432=512/243X1/2=256/243 - ri1
7. 256/243 X 4/3 = 1024/729 - ma3
   Now proceeding from 1024/729 will take us to very bigger fractions and we would not be able to obtain the remaining values among the 22, that we are trying to derive. Hence we abandon the value 1024/729 and instead take the value 45/32 which is very close to 1024/729.
   [1024/729 = 1.4046 45/32 = 1.4062]
   45/32 - ma3
8. 45/32 X 4/3 = 15/8 - ni3
9. 15/8 X 4/3 = 5/2
   5/22=5/2 X 1/2= 5/4 - ga3
10. 5/4 X 4/3 = 5/3 - dha3

5/3 X 4/3 = 20/9
20/92 = 20/9 X 1/2 = 10/9 - ri3

12. 10/9 X 4/3 = 40/27 - ma4 & pa
[64/45 = 1.4222
40/27 = .4814 3/2 = 1.5]

At this stage we reach the value which represents a note which is slightly lower than pa and slightly higher than cyutapañcama madhyama (ma4). The next cycle would yield a note of the value 160/81, which we would be slightly (81/80) less than sa and greater than ni4 and further continuance would present only the same notes as this cycle of fourth started with, namely, ma1, ni1 etc. except that they would be slightly less than their previous values, i.e., less by an interval of 81/80.

So this cycle stops at this stage.

We find that the 22 mathematical values listed earlier have all been derived through the Cycles of fifth and fourth, though we had to make slight shift from the some of the values to some other nearby values. Especially the values 5/4 of ga3 (antara- gándhára) and 6/5 of ga2 are obtained only after the shifts have been made.

Some of the features observed in these values are enumerated below.

1. The three ekasruti values are found occur in an interesting pattern among the notes.

81/80 - occurs between the first varieties of ri, ga, ma, dha & ni and their second varieties. Again it occurs between the third and the fourth varieties. e.g., between ri1 and ri2 & between ri3 & ri4.

It would be seen that this interval of 81/80 occurs in all 10 times, i.e., there are 10 intervals of 81/80 in one octave.

25/24 - occurs between the second and third varieties of ri, ga, ma, dha & ni. e.g., between ri2 and ri3.

It would be seen that this interval of 25/24 occurs in all 5 times. i.e., there are 5 intervals of 25/24 in one octave.

256/243 -occurs between the last variety of a svara and the first variety of the next, e.g., between sa and ri1 ri4 and ga1. In all there are 7 intervals of 256/243, namely, between sa and ri, ri and ga, ga and ma, ma and pa, pa and dha, dha and ni, ni and sa.

2. The interval of an octave having a value 2, is thus made up of 10 intervals of 81/80,
5 intervals of 25/24 and
7 intervals of 256/243.

If we were to arrange these intervals in the order in which they occur and combine (multiply) them together, we would get the value of a total octave. This has been shown below.

256/243 X 81/80 X 25/24 X 81/80 X 256/243 X 81/80 X
25/24 X 81/80 X 256/243 X 81/80 X 25/24 X 81/80 X
256/243 X 256/243 X 81/80 X 25/24 X 81/80 X 256/243 X
81/80 X 25/24 X 81/80 X 256/243 = 2

3. CONSONANCE AND DISSONANCE

Indian music is based on melody and Western music on harmony. An order of notes played or sung in succession constitutes melody. It has been recognised long ago that certain combination of tones produced a pleasing effect which results by the perfect concord between the related notes. This is known as consonance. The unpleasant relationship between two notes produces discord and it is known as Dissonance.

The quality of sound is calculated by the proportions in which the partials or overtone are combined with the fundamental. The famous scientist Helmholtz found out that all the dissonances are made by the unpleasant beats generated by cmponent tones and that consonance is formed by those tones which do not produce such beats. The roughness increases and decreases according to the interval between the two nearest ntes. The roughness increases and reaches its maximum when the interval between two notes is less than half tone. When the interval is less than this it is called the beating distance for 2 notes and naturally the sound produced with in this distance will be unpleasant and discordant. Dissonance due to beats will be produced if a partial tone is within the beating distance of another partial tone.

Consonance :

A pair of consonant notes are those which, sounded simultaneously, produce a smooth, pleasant, and agreeable impression. In this respect

we first think of 'unison'. Next to unison the 'octave' most naturally fits the definition. As mentioned above the reason for consonance can traced to the partial tones.

Let us take the first six harmonic partials of madhya sa and tara sa.

madhya-sa   s s p s g p
tara-sa   s s p
we see

a. that the higher note merely reinforces what is already present in the lower note, and that so long as the tuning is accurate no possibility of unpleasant beating arises.

b. that if the tuning is not accurate, beating occurs between every partial of the higher note and the corrsponding partial of thelower note. This explains why the octave is so sharply bounded by dissonance.

We take next the fifth (pa) and from the point of view of consonance, we can set out the partials as follows.

madhya-sa   s s p s g p
madhya-pa   p p r p

The consonance occurs due to the partials tara pa and atitara pa of madhya sa being reinforced by the same partials of madhya pa.

Here we also notice possibilities of dissonance because of beats, namely, between atitara sa & atitara ri and between atitara ri & atitara ga.

In the first case, i.e., the dissonance between atitara sa (of sa) and atitara ri (of pa), the partial tones that have the beats are 4th (of sa) & 3rd(of pa).

In the second case the beating partials are the 5th(of sa) & 3rd.(of pa).

We take next the note which is the fourth (suddha-ma)

madhya-sa   s s p s g p
suddha-ma   m m s m d

The partial of suddha-ma that reinforces one of madhya-sa is that of atitara-sa. There are also beating partials like the atitara-ma & atitara-pa and atitara-pa & atitara-dha.

On camparing ma and pa we find that upto the range of atitara sthayi,

i. pa has two partials that reinforce

ma has one partial that reinforces

ii. pa has two beating partials and a beating interval of the value 9/8, which is called the interval of major tone.

ma has two beating partials having a beating interval of major tone.

Pa is a better consonant note for madhya sa.

We give below the partials of some other notes and you may draw your conclusions regarding their suitability for being consonant notes of madhya-sa.

madhya-sa   s s p s g p
antara-ga   g g n g d
sadharana-ga   g g n g p
suddha-dha   d d g d
catuhsruti-dha   d d g d

Dissonance :

When we two take notes in unison and maintain the pitch of of one of them constant while that of the other is gradually raised, we find that the dissonance gradually increases, decreases and again continues to increase and decrease in this fashion.

For instance, if we take two notes tuned to madhya-sa and increase the pitch of one, the dissonance sets in immeadiately, and gradually decrease. The first marked minimum of dissonce come when the note is raised to the level of sadharana-ga. the next stages of minimum dissonance occur at -

antara-ga, suddha-ma, pa, suddha-dha, cat.dha and tara-sa.

It is noticed that the unison(sa & sa), the fifth (sa & pa), and the octave (sa & tara-sa) are free from dissonance. It is also seen that more perfect the consonance of an interval, the more sharply it is bounded by dissonance so that apasvaramin singing sadharana-ga is much less dissonant than an apasvaram in tara-sa or pa.

The reason for the dissonance, as stated earlier is due to the "beats" occuring between two notes of slightly varying pitch. The beats are

periodic loudness, the frequency of the beats being the difference of frequency of the two tones. If the beat-frequency is anything upto five or six per second the effect is not displeasing to the ear. As the difference in frequency of the two tones increases the beat-frequency increases and the sensation becomes less pleasant. Though the beats become too rapid to count there is no change in the character of the sensation, but the beats are now percieved only as a roughness.

The beat-frequency determining the dissonance will vary with the frequency range in which we are operating.

i. In the bass the beat-frequency would be around 16 per second. Dissonance would cease when the interval increases to 41 per second. In terms of svara interval this would be the beating between sa and cat.ri for maximum (major tone)and that between sa and prati-ma (tritone).

ii. the middle range the value would be 43 beats per second and for disappearing of dissonance would be 107 per second. In terms of svara intervals it would be,

maximum - sa and suddha-ri (semitone)

minimum - sa and sadharana-ga (minor third)

iii. In the high frequencies , the maximum dissonance occurs for 106 beats per second and the beat-frequency for disappearance of dissonance would be 265 per second.

maximum - slightly greater than semitone

minimum - 4/5th of a major tone.

When two musical notes are sounded togethr the resulting dissonance will therefore depend upon :

1. the interval between the pairs of beating partials - generally speaking, partials will be in the higher frequency range, and beating frequency range, and beating will be worse for semitones than for tones.

2.the stength of beating partials - this will depend on the quality of the notes, but in general the higher the order of the beating partials the less strong are these partials likely to be; it will also depend on the loudness of the two fundamental tones themselves.

LESSON - 9

RAGA LAKSANA

1. BHAIRAVI

Bhairavi is the janya of 20th melakarta natabhairavi.

árohana : sa ri gi ma pa dhi ni ṡa
avarohana : ṡa ni dha pa ma gi ri sa

The svara-s taken by this raga are sadja, catuhsruti rsabha, sadharana gandhara, suddha madhyama, pancama, suddha dhaivata catuhsruti dhaivata and kaisiki nisada.

Catuhsruti dhaivata is an anya svara, ekanya-svara bhashānga rāga. Anya svara is present in the scale itself. It occurs in the phrase like

p d n s, p d n s R, and p d n d nṠ.

The svakiya svara suddha dhaivasta is used in the phrases like p d p p d n d P.

It is a janya sampurna raga.

All the svaras of this raga can be used as graha svaras. But the most suitable ones are nisada, rsabha and catuhsruti- dhaivata.(e.g. Upacharamu, Dalauli)

rshabha, madhyama and pancama are amsa svaras.

ri, ma, pa, ni and catuhsruti dha are nyasa svaras. Catuhsruti-dhaivata is a hrasva nyasa.

e.g., d n r s n d, g r s N d raga-chaya svaras are ri, ga, ma & ni.

gandhara and nishada are kampita svaras.

r m G r s, m p d m are visesa prayogas.

Janta svara prayogas occur in this raga Janta svaras like - -

mm pp dd nn, rr gg mm pp are used frequently.

Datu svara prayogas like n ġ ṙ ġ ṡ ṙ , n ṙ ṡ r n ṡ are also common.

It is a major raga giving scope for elaborate alapana. Therefore it is used for singing pallavi.

This raga is suitable for singing slokas, padyas, etc. It figurs in geyanatakas and nrtya natakas. All types of musical forms like gita, svarajati, varna, krti pada, daru are found in this raga.

This raga corresponds to ancient tamil pan kausikam.

Sancara :

r g m r g r S - g r N d - n s r g m g r s - r g m p d P N d p d M p d n Ṡ - n
ṡ ṙ ġ Ṙ - ṙ ġ m ġ ṙ Ṡ - ġ ṙ ṡ N - ṙ ṡ n d P - m p d n ṡ - p d m p G r - g r
s N̦ d̦ n̦ S

Compositions:

Gita	sri ramacandra	dhruva	
Svarajati	kamakshi.	Chapu	Syama Sastri
Varna	Viriboni	Ata	Paccimiriyam Adiyappayya
Krti	Koluvaiyunnade	Adi	Tyagaraja
	Upacaramu	Rupaka	"
	Upacaramulanu	Adi	"
	Tanayunibrova	Adi	"
	Cintayama	Rupaka	Muttusvami Diksitar
	Balagopala	Adi	"
Tarangam	Jayajagokulabala	Rupaka	Narayanatirtha
Padam	Madati	Triputa	Ksetrajna
	Velavare	Adi	Ghanam Krsnayyar
Daru	Yaro yivaryaro	Adi	Arunachala Kavirayar

2 KAMBHOJI

Called also as Kambodi, Kambhoji is derived from the 28th. mela, Harikambhoji.

Arohana – s r g m p d ṡ
Avarohana – ṡ n d p m g r s

Only one svara is varja in the arohana and therefore it is called as sadava sampurna raga.

The svaras taken by the raga are sadja, catuhsruti rsabha, anatara gandhara, suddha madhyama, pancama, catuhsruti dhaivata, kaisiki nisada and kakali nisada.

Kakali nisada is the anya svara. Thus it is an ekanyasvara bhasanga raga. The anya svara figures in the phrase

s n p d s. The gita 'mandaradhara re' in this raga starts with the phrase ṡ n p d d ṡ.

Datu svara prayogas like r p m g s, r m g s, p d ġ ṙ ṡ figure in this raga.

Graha svaras are sa ga ma pa and da. Amsa svaras are ga and dha.

Nyasa svaras are ga ma pa.

Jiva svaras are ri and kai ni.

It gives scope for singing elaborate alapana. Therefore, it is chosen for singing pallavi slokas padyas and vrttas are sung in this raga. It is used in musical and dance dramas. All types of forms like gita, varna pada. javali etc are found in this raga.

Both trisruti dha 5/3 and catuhsruti dhaivata 27/16 are used in this raga. In the phrase

d n d p trisruti dhaivata is used, and in the phrase

s n p d s catuhsruti dhaivata is used.

The pan takkesi is the equivalent in tamiz system. In kathakali music this is known by the name kamodari.

Sancara:

m g r S n̦ p̦ d̦ S - n̦ d̦ p̦ d̦ s r g m G - m g m p d p d n D p - d ṡ n d p D - ṡ P d

ṡ ṙ ġ ṁ Ġ - ṁ ġ ṙ ṡ - ṡ n n d p p D - ġ ṙ ṡ n d p m g m g r s n̦ p̦ D̦ S

Compositions:

Gita	Mandaradhara re	Adi	-
Varna	Taruni	Adi	Fiddle Ponnusvami
	Sarasijanabha	Adi	Vadivelu
Krti	O Rangasayi	Adi	Tyagaraja
	Evarimata	"	"

	Ma janaki	"	"
	Sri raghuvaraprameya	"	"
	Sri subrahmanyaya	Rupaka	Muttusvami Dik.
	Devi ni pada	Adi	Syama sastri
	Tiruvadi caranam	Adi	Gopalakrsna Bharati
Padam	Yalane vanipai	Triputa	Ksetrajna
Azhagar kuravanji	Ivan yaro	Adi	Kavikunjara Bharati
Javali	Emi mayamu	Rupaka	Pattabhiramayya

3 MADHYAMAVATI

Madhyamavati is a janya raga derived from 22nd melakarta Kharaharapriya.

Arohana – s r m p n ṡ
Avarohana – ṡ n p m r s

Ga and dha are absent in both the arohana and avarohana. Therefore it is an auduva raga upanaga raga. The svaras taken by this raga are

Sadja, catuhsruti rsabha,suddhamadhyama, pancama, kaisiki nisada.

Graha svaras are sa, ri, ma, pa & ni

Amsa svara are ma and pa.

Nyasa svaras are sa, pa.

Raga-chaya svaras are ri,ma & ni Pratyahata gamaka lend beauty to this raga. Prayogas like

mr rs sn,rs sn np are common.

Pancama-varja janta phrases like "rr mm nn rr" occur.

Datu svara prayogas like m r p m n p s n are also used in this raga.

The equivalent pan is sendurutti.

Panchama varja janta prayogar like rr mm nn occurs frequently.

Sancara:

R r m p m r s - n s r s n p n s R s - r m p N - p N ṡ ṙ ṡ n p - m p N p m R

- m r p m n p ṡ n ṙ ṡ n Ṡ n P p m R S - N S n n N S

Compositions

Varna	Saraguna	Adi	Tiruvorriyur Tyagayyar
Krti	Alakalella	Rupaka	Tyagaraja
	Vinayakuni	Adi	"
	Ramakatha	Adi	"
	Dharmasamvardhani	Rupaka	Muttusvami Diksitar
	Palincu kamaksi	Adi	Syama Sastri
	Karpagame	Adi	Papanasam Sivan
	Parthasarathi	Rupaka	Ramanathapuram Srinivasa Ayyangar

4 KEDARAGAULA

It is a janya of 28th mela Harikambhoji.

Arohana – s r m p n ṡ
Avarohana – ṡ n d p m g r s.

In arohana ga and dha are absent and avarohana is sampurna. Therefore it is an auduva sampurna raga.

It is an upanga raga.The svaras taken by this raga are - sadja, catuhsruti rsabha, antara gandhara, suddha madhyama, catuhsruti dhaivata and kaisiki nishada.

Graha svaras are sa,ri, ma, pa, & ni.

Amsa svara is pa.

Nyasa svaras are ri and pa.

Raga-chaya svaras are ri and ni. They are also kampita svaras.

p d m and g m g R g r S are visesa prayogas.

Slokas, padyas and vrttas are sung in this raga.

It is used in musical and dance dramas.

It is tristhayi raga, having movement over all the three sthayis. Elaborate alapana can be sung in this raga.

Its equivalent in tamil music is pan gandhara-pancamam.

Sancara:

r m p m g R - r m p n Ṡ n d p - p n ṡ Ṙ - ṡ m̈ ġ Ṙ ġ ṙ Ṡ n s ṙ ġ ṙ n s r
s n d p - m p S p - d p m g R - m g r S - s N d p N S.

Compositions

Varna	Sami dayjuda	Adi	Tiruvottiyur Tyagayyar
	Viriboni	Jhampa	Rudrapatnam Venkataramayya
Krti	Tulasibilva	Adi	Tyagaraja
	Venuganaloluni	Adi	"
	Nilakantham	Rupaka	Muttusvami Diksitar
	Saraguna palimpa	Adi	Ramanatha-puram Srinivasa Ayyangar
	Prahlada varijianayana bhaktivijayam	Adi	Tyagaraja
rama-andarama	saundaryam natakam	"	Arunacala Kavirayar
Padam	Emandunamma	Triputa	Ksetrajna
Tarangam	Mangalalaya	Adi	Narayana Tirtha

LESSON - 10

RAGA LAKSANA (CONTD)

5 DHANYASI

It is a janya of 8th. mela hanumatodi.

Arohana : s g m p n ṡ
Avarohana : ṡ n d p m g r s

The svara-s occuring in this raga ara- sadja, suddha rsabha, sadharana gandhara, suddha madhyama, pancama, suddha dhaivata, kaisiki nisada.

Ri and dha are varja in arohana. Audava sampurna raga.

Upanga raga.

Graha svaras are sa, ga, ma, pa, ni.

Amsa svaras are ga and ni.

Nyasa svaras are pa and ni.

Ragachaya svaras are ga and ni. They are dirgha svaras and kampita svaras.

Tristhayi raga.

n ṡ p n m p is a ranjaka prayoga. p n ṡ d p is visesa prayoga.

Sancaras :

s g m p p m g r s - n s p n s g m p p m G - g m p n ṡ D p-p n ṡ D p N ṡ -
ṁ ġ ṙ ṡ - p n ṙ ṡ D p m p G - m g r S - nn s p n s.

Compositions :

Tanavarna	Nenarunci	Ata	Vina Kuppayyar
Padavarna	E maguva	Adi	Mysore Sadasiva Rao
Krti	Dhayaname	Adi	Tyagaraj
	Sangita jnanamu	Adi	"
	Mayuranatham	M.capu	Muttusvami Diksitar
	Paradevata	Adi	"
	Mangaladevataya	Rupaka	"

	Minalocani (Navaratnamalika)	M.capu	Syama Sastri
	Kanaka sabhapati	Adi	Gopalakrsna Bharati
Tillana	Dhim dhim tom	Adi	Pallavi Sesa Ayyar
Mangalam	Janakinayaka	Adi	Tyagaraja

6 VASANTA

It is a janya of the 17th melakarta suryakantam.

Arohana – s g m d n ṡ
Avarohana – ṡ n d m g r S

ri and pa are absent in the arohana and pa is absent in the avarohana. therefore it is an shadava raga.

It is an upanga raga.

The svaras taken by this raga are - catuhsrutidhaivata and kakali nisada.

Graha svaras are sa ga ma da.

Amsa svara is ma.

Nyasasvarasarema and dha.

Raga-chaya svaras are ga ma da & ni.

Pratyahata gamaka lends colour to this raga. Thus the phrases like rs sn nd dm sn nd dm mg can be used.

The phrase s m g m comes frequently.

Sancara :

s m g M - g m d n ṡ n d m g m d n ṡ - ṡ m g M g r s - n d n ṡ n d n d M - g m d n ṡ n d m - g m D M g M g r s - n d n s r S.

Compositions :

Varna	Ninnukori	Adi	Pedda Singaracaryulu
Krti	Ramacandra	Rupaka	Muttusvami Diksitar

	Natanam adinar	Ata	Gopalakrsna Bharati
Astapadi	Lalita lavanga	Adi	Jayadeva
Tillana	Jhanjhamtarita	Adi	Pallavi Sesayyar
Mangalam	Mangalam sri	Adi	Mysore Sadasiva Rao

7 SRIRAGA

It is a janya of 22nd melakarta Kharaharapriya.

Arohana – s r m p n s
Avarohana – s n p m r g r s or s n p d n p m r g r s

Dha does not figure in the compositions of Tyagaraja. In those of Muttusvami Diksitar, it occurs in an alpa prayoga "p d n p m". It is an example of a raga in which alpa prayoga is found in the aroha-avaroha.

So it is an auduva vakra sadava raga according the first version and auduva vakra sampurna raga according the second version.

Avarohana is vakra - dvisvara vakra or ekasavara vakra raga.

The svara-s occuring are - sadja, catuhsruti rsabha, sadharana gandhara, suddha madhyama, pancama, catuhsruti dhaivata and kaisiki nishada.

Upanga raga and a tristhayi raga.

This raga belongs to the traditional ghanaraga pancaka.

Graha svaras are sa, ri, pa,ni.

Amsa svara is ri.

Nyasa svaras aresa, ri,pa.

ri and ni are raga chaya svaras.

Datu svara prayogas that give ranjakatva are

r m r p m n p ṡ n ṙ, ṡ ṙ n s p n m p r p m r g g r s.

Sancara :

Rg r s - n r s n p - n s r g R - r m P - m p n p N p m r G r s r m p n Ṡ - n ṡ ṙ ṡ n P - r m p m r G r s - n R s n p N - p m r G r - s n p N S

Compositions :

Gita	Minaksi jaya kamaksi	Dhruva	
Varna	Sami ninne	Adi	Garbhapurivasar
Krti	Namakusuma	Adi	Tyagarja
	Endaro mahanubhavulu (ghanaraga pancaratnam)	Adi	Tyagaraja
	Sri varalaksmi	Rupaka	Muttusvami Diksitar
	Sri kamalambike	Khanda eka	"
	Sri muladhara	Adi	"
	Tyagaraja mahaddhvaja	Adi	"
	Karunajudu	Adi	Syama Sastri
	Vanajasana	Rupaka	Subbaraya Sastri

8 ANANDABHAIRAVI

It is a janya of 20th Mela Natabhairavi.

Arohana – s g r g m p d p s
Avarohana – s n d p m g r s

It is vakra-sadava, krama-sampurna raga. Arohana alone is vakra and has dvisvara vakra arohana.

The svaras taken by it are - sadja, catuhsruti rsabha, sadharana gandhara, antara- gandhara, suddha madhyama, pancama, suddha dhaivata, catuhsruti dhaivata, kaisiki nishada and kakali nishada.

The anya svara catuhsruti dhaivata. Dhaivata is incorported in the scale like in bhairavi. The svakiya svara is not sung in the arohana and avarohana. The other anya svaras, antara gandhara and kakali nishada are heard in some rare prayogas, like

m g g m , s n n s.

The phrases "p d p m" and "m d p m" contain svakiya svara. Graha svaras are sa, ga, pa, ni.

Amsa svara is pa.

Nyasa svaras are sadharana-gandhara, kaisiki-nisada, madhyama and pancama.

Raga-chaya svara are sadharana-gandhara, madhyama and kaisiki nisada.

"p n S" is an arsa prayoga i.e., an obsolete prayoga.

p n p, s g m, p d n s are visesha prayogas. sadharana-ga and kaisiki-nisada are kampita svaras.

This raga does not have sancaras below mandra sthayi nisada.

Sancara :

g m P - p m g r - G m p m g r r G s - r s N - s m g r g m p d m P - m p Ṡ ṡ n - ṡ n ṡ *ṁ ġ ṙ* Ṡ - n ṡ *ṙ ġ ṙ* Ṡ - ṙ ṡ n d P - g m p m g r r G r S.

Compositions :

Gita	Kamalasulocana	Adi	
Svarajati	raveme	Adi	Sobhanadri
Varna	Samini rammanave	Ata	Syama Sastri
Krti	O Jagadamba	Adi	"
	Himacalatanaya	M.eka	"
	Marivere (Navaratnamalika)	M.capu	"
	Nike teliyaka	Adi	Tyagaraja
	Manasaguruguha	T.eka	Muttusvami Diksitar
	Tyagaraja Yogavaibhavam	Rupaka	"
	Anandesvarena	M.eka	"
	Kamalamba samraksatu	M.eka	"
	Kanikaramu	Rupaka	Vina kuppayyar
Padam	Mancidinam	Triputa	Ksetrajna